DEVELOPMENT OF INTERIM CHEMICAL PROTECTIVE OVERGARMENT (ICPO)

NAVY CLOTHING AND TEXTILE RESEARCH FACILITY

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The Navy Clothing and Textile Research Facility was tasked by the Naval Sea Systems Command to develop an interim chemical protective overgarment (ICPO). When compared to the current chemical protective overgarment (CPO), the ICPO development was to achieve improved fire protection; improved chemical agent protection with increased wear and storage life; increased tolerance time, working in hot-humid environments; and improved compatibility with chemical defense (CD) and flight deck (FD) individual protective equipment (IPE). These near term improvements to the current CPO, included the replacement of the outer shell and activated charcoal inner liner materials, and needed design changes, which included the enlargement of the current hood to accommodate the cranial helmet and aural sound protectors worn by flight deck personnel. The goals to improve fire protection and chemical protection were achieved, and heat strain was equivalent to the current CPO. Compatibility with all CD and FD IPE was not achieved, particularly with respect the hood/chemical mask interface. As a result of these findings, further efforts to develop the ICPO were abandoned, and the United Kingdom (UK) G Specification liner was substituted by the current UK F Specification liner in the CPO.

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INTRODUCTION

The Navy Clothing and Textile Research Facility (NCTRF) was tasked by the Naval Sea System Command (NAVSEASYSCOM) to develop an interim chemical protective overgarment (ICPO), pending the development of an advanced chemical protective overgarment (ACPO). The characteristics of the current CPO to be improved were fire protection, tolerance time to heat while wearing the overgarment (OG) in hot/humid conditions (reduced heat strain), and improved chemical protection, with increased wear and storage life. Compatibility with other individual protective equipment (IPE) used in conjunction with the ICPO was also evaluated. These near term improvements to the current CPO included: replacement of its outer shell and inner charcoal liner materials, and needed design modifications, such as the enlargement of the current hood to accommodate the cranial helmet and aural sound protectors worn by flight deck personnel.

The current Navy CPO is the United Kingdom's (UK) MK III OG which consists of a smock with integrated hood and separate trousers. The outer shell material is a 70/30% modacrylic/nylon twill and the liner material consists of activated charcoal particles sprayed and bonded to a multi-fiber cloth (anti-gas cloth, UK specification UK/SC/3346, revision F). The candidate materials for the ICPO were a Fire Retardant and Water Repellent Treated (FRT/WRT) 100% cotton and 50/50% polyester/cotton for the outer shell, and a newer version of the UK's anti-gas cloth liner, UK/SC/3346, revision G. The new anti-gas cloth is claimed to have improved chemical protection and wear properties. Design changes to the current CPO (zippered front opening for the smock) were made to reduce heat strain for Military Oriented Protective Posture (MOPP) 2 and 3 (MOPP level descriptions are provided in Appendix A); and compatibility with the Navy's MK V and MCU-2/P chemical protective masks, and other chemical defense (CD) and flight deck (FD) IPE items (butyl gloves and footwear covers, and cranial helmet, aural sound protectors, etc.).

Evaluation of the new ICPO included: physical, vertical flammability resistance, heat protection, biophysical, physiological, and chemical agent laboratory tests of the candidate materials and ICPOs; and flame envelopment, compatibility, and operational demonstration (OPDEMO) field tests of the prototype OGs.

Activities involved in the evaluation of the ICPO were:

Naval Air Engineering Center (NAEC)	-	Physical Compatibility with CD and FD IPE
Naval Surface Weapons Center (NSWC)	-	Simulated Chemical Agent protection with CD and FD IPE
Naval Air Development Center (NADC)	-	Flame Envelopment Tests

INTRODUCTION (Continued)

Army Dugway Proving Ground (DPG)	-	Chemical Agent Tests of New and Worn Materials
Fort McClellan, Chemical Defense Training Facility (CDTF)	-	OPDEMO, Land Based
Naval Air Station, Coronado, CA Amphib CB-1	-	OPDEMO, Port Side Based
USS MOBILE, LKA-115	-	OPDEMO, Sea Based
USS CROMMELIN, FFG-37	-	OPDEMO, Sea Based
USS JARRETT, FFG-33	-	OPDEMO, Sea Based
USS DULUTH, LPD-6	-	OPDEMO, Sea Based
USS CONNOLLY, DD-979	-	OPDEMO, Sea Based

LKA - Amphibious Cargo Ships
FFG - Guided Missile Frigate
LPD - Amphibious Transport Dock Ships
DD - Destroyers

The findings of this evaluation were as follows:

1. Of the two (2) ICPO candidate outer shell materials, FRT/WRT 100% cotton and FRT/WRT 50/50% polyester/cotton, the FRT/WRT 100% cotton material had the best physical properties. The cotton material was lighter in weight, had an equivalent breaking strength, higher tear strength, lower stiffness, better abrasion resistance, equal spray resistance, and higher hydrostatic resistance than the polyester/cotton material. The only physical property where the polyester/cotton material was better than the cotton material, was its higher air permeability.

2. The FRT/WRT 100% cotton and FRT/WRT 50/50% polyester/cotton ICPO candidate outer shell materials, had equivalent vertical flame resistance, and radiant and convective/radiant heat protection.

3. Abrasion tests of the anti-gas cloths evaluated for the ICPO, UK G Specification cloth, with and without a nylon scrim backing, versus the UK F Specification cloth used in the current CPO, showed that the UK G Specification cloth with the nylon

scrim backing had the best abrasion resistance, less charcoal loss than the other two (2) cloths. The UK G Specification was second best, with less charcoal loss than the UK F Specification cloth.

4. Heat protection tests of the ICPO candidate material assemblies; FRT/WRT 100% cotton outer shell and UK G Specification anti-gas cloth, and FRT/WRT 50/50% polyester/cotton outer shell and UK G Specification anti-gas cloth; indicate that the cotton anti-gas cloth assembly provided more heat protection in the radiant and convective/radiant heat tests. The estimated time to burn injury in the radiant heat tests was 35 seconds for the cotton assembly and 31 seconds for the polyester/cotton assembly. In the convection/radiant heat tests, the estimated time to burn injury was ten (10) seconds for the cotton assembly and nine (9) seconds for the polyester/cotton assembly.

5. In flame envelopment tests of the ICPOs and current CPO, cotton-G Specification anti-gas cloth ICPO, polyester/cotton-G Specification anti-gas cloth ICPO, and modacrylic/nylon-F Specification anti-gas cloth CPO; the polyester/cotton ICPO performed best, and the cotton ICPO was considered second best. In three (3) tests with the polyester/cotton ICPO, there was no burn injury, and an after flame time of only four (4) seconds occurred in one (1) of the three (3) tests. In one (1) of the three (3) tests with the cotton ICPO, there was a 3.5% body area burn injury, and an excessive after flame of 32 seconds before the flames were quenched with a fire extinguisher. In the other two (2) tests with the cotton ICPO, there was no burn injury, and an after flame of only two (2) seconds occurred in one (1) of these two (2) tests. In two (2) of three (3) tests with the modacrylic/nylon CPO, there was an excessive after flame of 30 seconds before the flames were quenched with a fire extinguisher. In these tests with the modacrylic/nylon CPO, the modacrylic/nylon outer shell melted, exposing the anti-gas cloth to the fire.

6. Biophysical tests of the candidate ICPOs and the current CPO at MOPP Levels 3 and 4, showed no difference between the ICPOs and the CPO. Their thermal insulation (CLO), water vapor permeability (Im), and Im/CLO values for each MOPP level condition was equivalent. The difference between the Im/CLO values, for MOPP Levels 3 and 4 for all overgarments, indicate an increase of 56-63% in body heat dissipation for MOPP Level 3 compared to MOPP Level 4.

7. A physiological evaluation of the candidate ICPOs and the current CPO at MOPP Level 4, in hot-dry and hot-humid environments with a moderate work load, found that there was no statistical difference in tolerance time between the overgarments ($p > 0.05$).

INTRODUCTION (Continued)

8. HD liquid chemical agent tests of new material assemblies used in the ICPOs and current CPO, showed the polyester/cotton-G Specification anti-gas cloth ICPO assembly, with and without the nylon scrim, had a breakthrough time of 32 hours, the cotton-G Specification anti-gas cloth ICPO assembly, with and without the nylon scrim, had breakthrough times of 32 and 16 hours, respectively, and the modacrylic/nylon-F Specification anti-gas cloth, had a breakthrough time of 16 hours. In five (5) of six (6) tests employing the G Specification anti-gas cloth, with and without the nylon scrim, breakthrough times were 50-100% longer (24-32 hours) compared to the F Specification anti-gas cloth (16 hours).

9. HD vapor chemical agent tests of new material assemblies used in the ICPOs and current CPO, indicate that the cotton and polyester/cotton-G Specification anti-gas cloth ICPO assemblies, with and with the nylon scrim, and the modacrylic/nylon-F Specification anti-gas cloth CPO assembly had an equivalent breakthrough time of 16 hours.

10. The results of HD liquid and vapor chemical agent tests of worn overgarment material assemblies were inconclusive, because of the variability in the test results, and lack of information on the history of the materials, and the amount of time the overgarments were worn.

11. Physical and simulated chemical agent compatibility tests of the ICPOs, showed poor compatibility between the MCU-2/P and MK V masks and the enlarged hood of the ICPO, with and without the cranial helmet worn by flight deck personnel. Spray tests of the ICPO, with the CD and FD IPE, using a chemical agent stimulant, indicated no stimulant penetration of the ICPO.

12. Operational demonstration tests of the ICPOs aboard five (5) ships, one (1) port side unit, and two (2) land based sites, where simulated chemical defense drills were performed with CD and FD IPE, showed that the most significant deficiency of the ICPOs, was the compatibility of the enlarged hood with the MCU-2/P and MK V masks, with and without the cranial helmet.

13. Of the goals established for the ICPO, improved fire protection, reduced heat strain, involved chemical protection, and compatibility with the IPE, the improved fire protection and chemical protection goals were achieved. Heat strain was equivalent to that experienced with the current CPO. The incompatibility of the enlarged hood of the ICPO with the chemical masks, with and without the use of the flight deck cranial helmet, requires a redesign of the hood, if any further development of the ICPO is to be considered.

INTRODUCTION (Continued)

This report describes the characteristics of the materials and design used for the ICPO, provides the methods and procedures used, and presents the results obtained from the various laboratory and OPDEMO tests conducted.

BACKGROUND

In 1980, the Navy was still using impregnated clothing with CC-2 chloroamide as its permeable chemical protective OG. Because suitable supplies were limited, and no manufacturing source existed, the Naval Surface Weapons Center, Dahlgren, Virginia, as the Navy's lead laboratory for chemical agent protection, initiated an evaluation of other chemical protective OGs to determine their suitability for Navy shipboard use. The U.S. Army, Canadian, and UK chemical protective OGs were selected for evaluation and judged with respect to Navy needs and requirements. The result of this study was the selection of the UK's MK III chemical protective OG as the most suitable for the naval environment, being compatible with the Navy's MK V chemical agent protective mask and packaged to minimize storage requirements. The NCTRF was then tasked to prepare a purchase description for procurement of the OG from the UK through the Defense Personnel Support Center. When one of the domestic manufacturers of the Army's OG learned of this procurement, the company filed a complaint with its congressman, which led to an agreement with the Navy to provide an opportunity for domestic manufacturers to demonstrate they could provide an OG which met Navy requirements.

The NCTRF was assigned the responsibility to prepare the Navy's requirements document, which was promulgated to domestic industry for their submission of OGs that met the requirements. OGs were submitted by several companies and evaluated by the NCTRF with the aid of various Navy and Army activities. The UK MK III OG was found to be more in conformance with the Navy requirements than any of the other submissions. Adoption and procurement approval was obtained, and the UK OGs were procured from the UK.

Although the UK MK III OG met Navy requirements, some of its performance characteristics were marginal, which eventually resulted in a program to develop an ACPO for the long term and the ICPO for the near term.

DESCRIPTION OF MATERIALS

Outer Shell Materials

The two (2) candidate outer shell materials evaluated for the ICPO were a 100% cotton and a 50/50% polyester/cotton with FRT/WRT finishes. The FRT finishes were a tetrakis hydroxymethyl phosphonium chloride (THPC, Westex) for the 100% cotton, and Flamex (Galey and Lord) for the 50/50% polyester/cotton. A fluorocarbon type WRT finish was used for both fabrics. The modacrylic/nylon outer shell of the CPO is finished with a silicone type WRT. The nominal weights of the ICPO candidate materials were 5.0 and 6.0 oz/yd^2 for the 100% ICPO cotton and 50/50% polyester/ cotton materials, respectively. The nominal weight of the modacrylic/nylon outer shell fabric used with the current CPO is 3.5 oz/yd^2.

Liner Material

The liner material used with the ICPO was as described in the UK's G revision specification for the anti-gas cloth, and was employed with and without a nylon scrim backing. The scrim was used to reduce the abrasion between the activated charcoal bonded to the anti-gas cloth and the undergarment materials worn. The liner material used with the modacrylic/nylon outer shell of the current CPO is described in the UK's F revision specification for the anti-gas cloth. The nominal weight for the F and G revision liners is 6.0 oz/yd. The difference between the F and G revision liners were the addition of an oil repellent treatment and 45 g of activated charcoal per square meter to the G revision cloth liner, instead of the 40 g per square meter used with the F revision cloth liner. The activated charcoal characteristics were also different; the G Specification version conforming to UK specifications TS 10253, Charcoal, powdered types 2000, while the F specification version conformed to UK specification TS 647, Charcoal, Activated Nutshell powdered. Vapor penetration time to a distilled mustard (HD) chemical agent liquid challenge, using UK specification agent test procedures, is twice as long with the G Specifications anti-gas cloth compared to the F Specification version (160 min. versus 80 min.).

OVERGARMENT DESIGN

The ICPO design had a smock top with an attached enlarged hood and separate trousers.

Smock (Figure 1)

The smock had a front zipper which was offset at the center of the upper torso area of the smock up to the right side of the hood opening, and was covered with a flap secured by a hook and pile fastener. An enlarged hood was used to accommodate the cranial helmet and aural sound protectors (FD IPE) worn by flight deck personnel, and employed a center gusset panel which could be adjusted to reduce the size of the hood when the helmet and aural sound protectors were not worn. The hood opening was adjustable to accommodate the Navy's MK V and MCU-2/P chemical protective masks, and the opening was secured with a drawcord having a double barrel lock. The sleeves had inner elasticized wristlets, with the gauntlet of the chemical protective butyl gloves worn between the wristlets and outer sleeves. The sleeves were secured to the glove gauntlets with hook and pile fasteners. The waist of the smock was secured by an elasticized drawcord, and a horizontal bellows adjustment was located in the lower back of the smock to prevent a gap between the trousers and smock when bending. Two (2) front pockets with flap closures secured by hook and loop fasteners were located symmetrically on both sides of the front zipper in the lower torso area of the smock. Butyl elbow patches were used to reduce abrasion in these areas.

Trousers (Figure 2)

The trousers had loop type attachments in the front and rear waist areas to accommodate suspenders, and hook and loop attachments at the front center of the waist to adjust the size of the waist. Hook and loop attachments were also located at the trouser cuffs to secure them over the butyl footwear covers. Pockets with flaps secured with hook and loop fasteners were located at the center side of each leg. Butyl knee patches were used to reduce abrasion in these areas.

The NAEC recommend the use of the enlarged hood and butyl patches in the knee areas, based upon their independent evaluation of the UK MK III CPO for different flight deck operational scenarios.

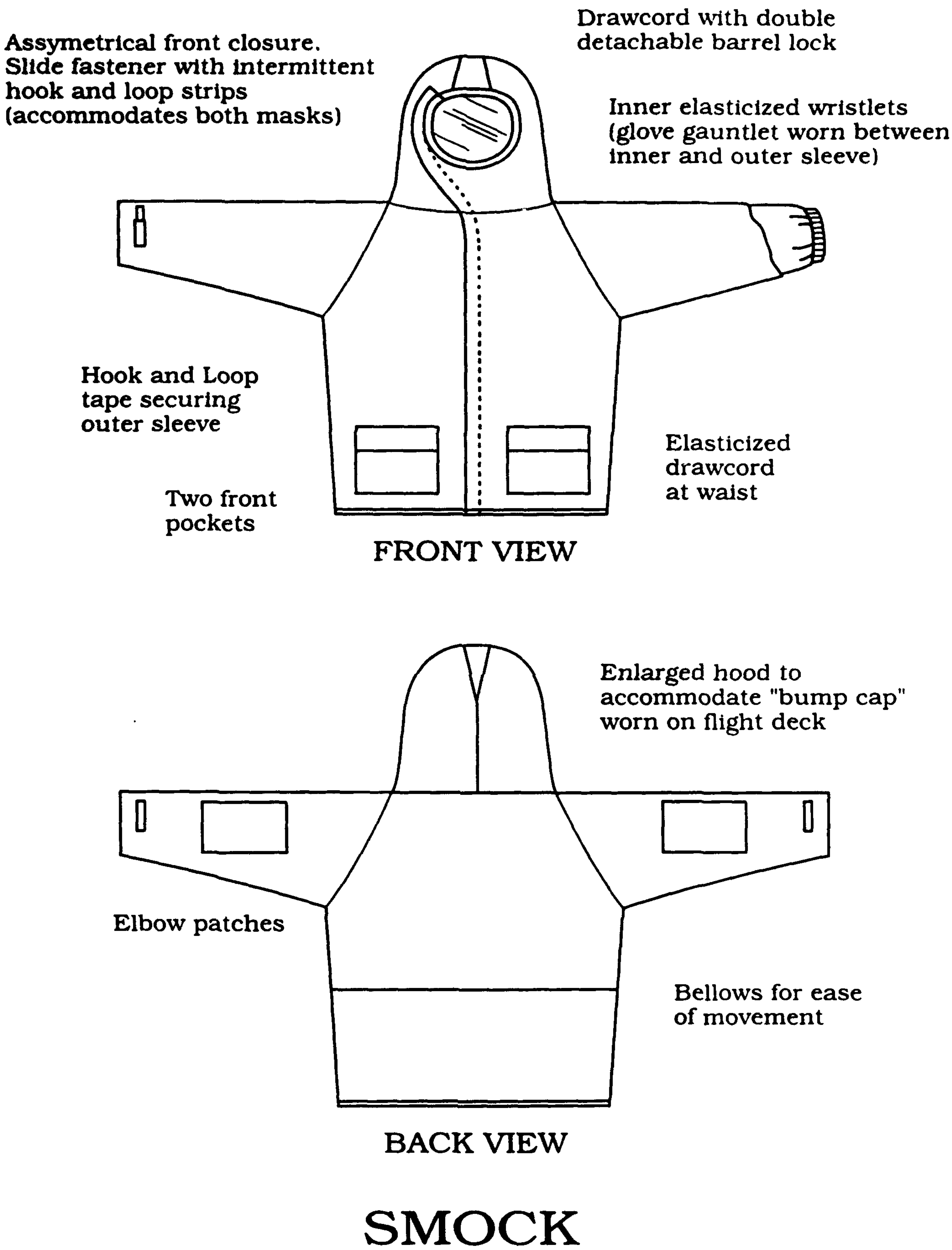

FIGURE 1. Interim Chemical Protective Overgarment with Enlarged Hooded Smock

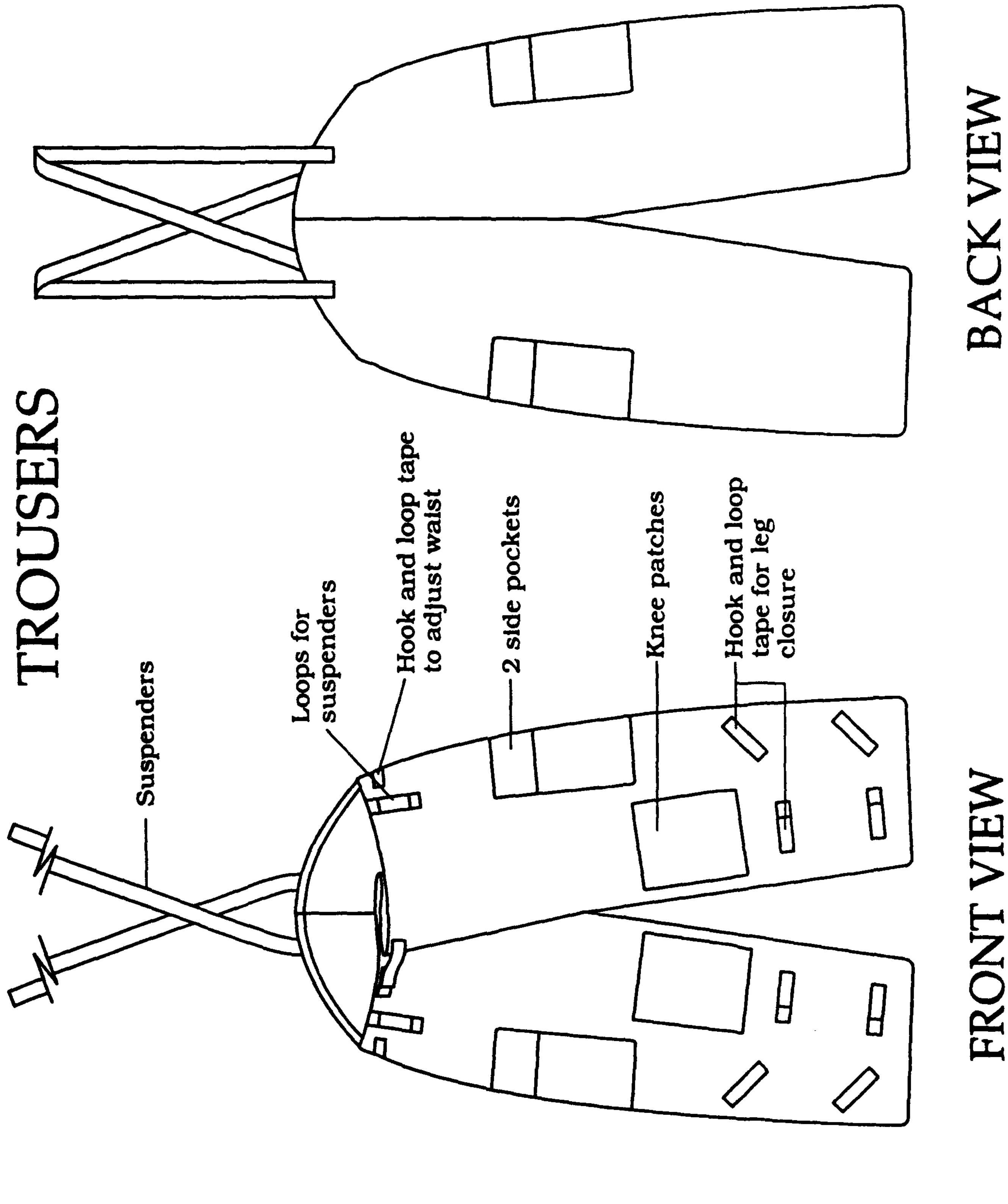

FIGURE 2. Interim Chemical Protective Overgarment Trousers

METHODS AND PROCEDURES

Material Physical Properties

The test procedures employed are described in Federal Standard for Textile Test Methods (FSTTM) No. 191 A, and in American Society of Testing Materials (ASTM), Standard Test Methods (Table I).

Vertical Flammability Resistance

The vertical flammability resistance of the candidate outer shell materials was determined using Test Method 5903, FSTTM. Data on after flame time (AFT), after glow time (AGT), and char length (CL) were obtained. Five (5) determinations were made on each material and the results averaged.

TABLE I. Test Methods for Determining Properties of Textile Materials

Property	Title	Test Method
Weave	Visual	
Weight	Weight of Textile Materials, Small Specimen Method	FSTTM 5041
Ends/Pick Per Inch	Yarns Per Inch, Length in Woven Cloth	FSTTM 5050
Break Strength	Strength and Elongation, Breaking of Woven Cloth-Grab Method	FSTTM 5100
Tear Strength	Tear Resistance of Woven Fabrics by Falling-Pendulum (Elmendorf) Apparatus	ASTM D1424
Stiffness	Stiffness of Cloth, Direction; Cantilever Bending Method	FSTTM 5202
Seam Efficiency	Sewability of Woven Cloth; Seam, Efficiency Method	FSTTM 5110

METHODS AND PROCEDURES (Continued)

TABLE I. Test Methods for Determining Properties of Textile Materials

Property	Title	Test Method
Abrasion Resistance	Abrasion Resistance of Cloth; Flexing, Folding Bar (Stoll) Method	FSTTM 5300
	Abrasion Resistance of Cloth; Oscillatory Cylinder (Wyzenbek) Method	FSTTM 5304
Water Resistance, Spray Method	Water Resistance of Cloth with Hydrophobic Finish; Spray Method	FSTTM 5526
Hydrostatic Resistance	Water Resistance of Cloth; Low Range, Hydrostatic Pressure Method	FSTTM 5514
Air Permeability	Permeability to Air, Cloth Calibrated Orifice Method	FSTTM 5450

Heat Protection

Radiant Heat Exposure

Materials were exposed to a radiant heat flux of 0.5g cal/cm^2/sec. for 60 seconds. A heat flux transducer in contact with the back of the sample was used to measure the heat flux transmitted through the sample. The radiant heat flux level chosen was equivalent to standing four (4) feet upwind from the edge of a 20 foot diameter fuel fire.[1] Five (5) tests were performed on each sample and the results averaged. The relationship between the measured heat flux transmitted through the sample and the exposure time was converted to burn injury time estimates using data developed by Stoll and Chianta.[2] A radiant thermal energy test apparatus was employed for these measurements.[3]

Convection and Radiant Heat Exposure

Materials were exposed to a 50/50% convection/radiant heat flux of 2 g cal/cm^2/sec for two (2) seconds using a thermal protective performance test apparatus.[4] This exposure level was equivalent to being at the edge of a significant fuel fire. Single layer samples were tested with a Heat Energy Measurement (HEM) transducer spaced 0.25 in. from the back of the sample. Material assemblies were tested with the HEM in contact with the back of the material assembly. Five (5) specimens were tested for each sample and the results averaged. As in the radiant heat tests the heat energy transmission results were converted to burn injury time estimates.

METHODS AND PROCEDURES (Continued)

Flame Envelopment Tests[5]

Fuel fire tests were conducted at NADC to determine the degree of fire protection provided by the candidate ICPOs. The tests were conducted using fiberglass manikins coated with a fire resistant paint. Paper temperature sensors mounted on leather patches were located at 36 sites on the manikins. There were four (4) on the head, ten (10) on the torso, four (4) on each arm, eight (8) on each leg, two (2) on each hand, and one (1) on each foot. Percent body area burn injury was based on data from Hardy, et. al. The head and the feet each representing 7% of the body area, and the torso, arms, hands, and legs representing 35, 14, 5, and 32 percent of the body area, respectively. The manikins were dresses with the current CPO (UK MK III) and the ICPOs, MK V mask, and butyl gloves and footwear covers. The under clothing were the Navy's FRT cotton chambray shirt and denim trousers utility uniform, cotton t-shirt and shorts, wool socks, chukka shoes, and cotton gloves.

Nine (9) OGs were evaluated consisting of the following:

CPO	Outer Shell	Anti-Gas Cloth	Number Tested
UK MK III	Modacrylic/ Nylon	F Specification	3
ICPOs	FRT/WRT 100% Cotton	G Specification	2
	FRT/WRT 100% Cotton	G Specification with Nylon Scrim	1
	FRT/WRT 50/50% Poly/Cotton	G Specification	2
	FRT/WRT 50/50% Poly/Cotton	G Specification with Nylon Scrim	1

The fire pit was 20 by 30 feet and JP-4 was used as the fuel. The manikins were propelled through the fires for two (2) seconds at an average expected heat flux of 2 g $cal/cm^2/sec$. Heat flux transducers mounted in the center area of a metal frame used to carry the manikins through the fire, measured the heat flux level.

Biophysical Evaluation

Thermal insulation (CLO) and water vapor permeability (Im) tests were conducted with the NCTRF Thermal Manikin (TM) on the UK MK III CPO and two (2) ICPOs, with FRT/WRT cotton and polyester/cotton outer shells and the G specification anti-gas cloth. The CD IPE worn with the OGs were the MCU-2/P chemical protective mask, and butyl gloves and footwear covers. The tests were conducted at MOPP levels 3 and 4. For MOPP 3 the OG, mask, and footwear covers were worn, and the smock hood and butyl gloves were not worn. The ICPO's smock was worn open. The MK III smock cannot be worn open. For MOPP 4, all CD IPE were worn, the ICPO smock was secured, and the hood of all OGs was secured around the mask and head, and the butyl gloves donned. The underclothing worn on the TM was the Navy's FRT chambray shirt and denim trousers utility uniform, wool socks, and chukka shoes. To simulate sweating in the Im tests, the TM was also dressed in a cotton skin underwear which covers its whole body, and which was equipped with a system of porous tubing integrated into the cotton skin. External controls regulated the amount of water delivered to all parts of the cotton skin. The Im tests measure the effectiveness of a garment or garment assembly to allow cooling of personnel by determining the cooling effect provided by the water evaporated at the skin, based on the ease of flow of the water vapor through the garment structure to the external environment.

Thermal insulation tests were conducted with a TM skin temperature of 36°C, and an ambient condition of 20°C and 50% relative humidity (RH). In the Im tests the skin temperature of the TM was also 36°C, and the ambient condition was 27°C and 48% RH. The windspeed was 0.7 mph for the thermal insulation and Im tests.

Physiological Evaluation[6]

The UK MK III CPO and two (2) candidate ICPOs with FRT/WRT 100% cotton and 50/50% polyester/cotton outer shells and G Specification anti-gas cloth were evaluated in a hot-dry and a hot-humid environment. The tests were conducted at MOPP Level 4 with the test subjects dressed in the OGs and CD IPE; MCU-2/P chemical protective mask, butyl gloves with cotton liners, and butyl footwear covers. For MOPP 4, the OGs were closed and the smock hood was secured around the mask and head. The mask filters were removed in these tests to limit resistance to breathing. The underclothing was the Navy's FRT cotton chambray shirt and denim trousers utility uniform, cotton T-shirt and shorts, and athletic socks and sneakers were worn instead of the wool socks and chukka shoes normally worn in a naval work environment.

METHODS AND PROCEDURES (Continued)

The hot-dry environment was 49°C (120°F) with a 20% RH and a 2.2 m/s (5 mph) wind, and simulated conditions at a shore-based operation in the Persian Gulf. The hot-humid environment was 35°C (95°F) with a 75% RH and a 4.5 m/s (10 mph) wind, and simulated conditions which might occur on the flight deck of a carrier operating in the Persian Gulf. All tests were scheduled for three (3) hours.

Seven (7) heat acclimated male test volunteers were exercised at a light to moderate ork rate of 300 watts (walked on a level treadmill at 1.3 m/s (3 mph) for 25 minutes and sat for five (5) minutes every half hour), and each volunteer was tested six (6) times while wearing each of the three (3) OGs. During the exposures, measurements of rectal temperature, skin temperatures (chest, arm, and leg), and heart rate were taken. The rectal and skin temperatures were measured at two (2) minute intervals, and heart rate was measured at the 15th and 25th minute of each 25 minute exercise cycle. Electrocardiograms were obtained from three (3) chest electrodes (CM5 placement) and continuously displayed on an oscilloscope and cardiotachometer unit. Total body sweating rate was calculated from pre- and post-test nude body weights, adjusted for water consumption.

Tests were terminated if rectal temperatures exceeded 39.5°C (103.1°F), or rising at a rate greater than 0.5°C (1°F) in five (5) minutes; heart rate exceeding 180 beats per minute for five (5) minutes continuously during exercise, or 160 beats per minute during rest. A volunteer was also removed if he exhibited signs of impending heat injury, such as syncope, dry skin, or other unusual distress, or was unable to walk or continue to walk unassisted.

The data were statistically analyzed using repeated measures analyses of variance. The data from the two (2) different environments were treated separately. The three (3) OGs were compared to each other. The rectal temperature, skin temperature, and heart rate data were analyzed using two-way analyses of variance (OG/time). For the rectal and skin temperature analyses, data points at ten (10) minute intervals were used (minutes 10, 20, 30, etc.). For the heart rate analyses, the recorded data points were used (minutes 20, 30, 50, 60). Because volunteers dropped out of the heat exposures early, the data was statistically analyzed only up to 60 minutes for the hot-dry environment and up to 70 minutes for the hot-humid environment. The sweating rate data were analyzed using one-way analyses of variance (OG). Missing data points were estimated using least squares and degrees of freedom adjusted accordingly. Significance was accepted at the 0.05 level. Tukey's test was used to locate the significant differences.

METHODS AND PROCEDURES (Continued)

Chemical Agent Tests[7]

Chemical agent tests were conducted by DPG. The new materials evaluated were:

Outer Shell	Anti-Gas Cloth
Modacrylic/Nylon	UK F Specification UK G Specification UK G Specification with Nylon Scrim
FRT/WRT 100% Cotton	UK F Specification UK G Specification UK G Specification with Nylon Scrim
FRT/WRT 50/50% Poly/Cotton	UK F Specification UK G Specification UK G Specification with Nylon Scrim

For worn OGs, the materials samples evaluated were taken from the smock (S) and the trousers (T). The materials evaluated were:

OG Number	Item	Outer Shell	Anti-Gas Cloth
1	S T	Modacrylic/Nylon	UK F Specification
2	S T	FRT/WRT 100% Cotton	UK G Specification
3	S T	FRT/WRT 100% Cotton	UK G Specification with Nylon Scrim
4	S T	FRT/WRT 50/50% Poly/Cotton	UK G Specification
5	S T	FRT/WRT 50/50% Poly/Cotton	UK G Specification with Nylon Scrim

METHODS AND PROCEDURES (Continued)

The tests performed by DPG were the Liquid Agent Contamination/Vapor Penetration Method (L/V test), and the Vapor Agent Contamination/Vapor Penetration Method (V/V test). The detailed procedures for these tests are provided in CRDC-SP-84010 **Laboratory Methods for Evaluating Protective Clothing Systems Against Chemical Agents.** The agent used was distilled mustard (HD). In all tests the Navy's FRT 100% cotton chambray shirt and 100% cotton T-shirt materials were used under the OG materials. In the L/V tests a 0.5 mil polyethylene film was used under the test samples, and a polyethylene disk was used separately as a control. The HD contamination density in the L/V tests was two (2) 1 mg drops per m^2 (2 mg/m^2) applied at 0, 8, 16, 24, 32, and 40 hours, and 20 micrograms/liter in the V/V tests for the new and worn materials. Five (5) replicates were performed for each material assembly. In the L/V and V/V tests, vapor penetration data were obtained at 8, 16, 24, 32, 40, and 48 hours for the new and worn materials.

Compatibility Tests[8,9]

Physical Compatibility

Initial tests to determine the compatibility of a NAEC modified UK MK III OG with CD and FD IPE were conducted by NAEC. The design of the UK MK III OG had been changed to include an enlarged hood that would allow the cranial helmet and aural sound protectors FD IPE to be worn under the hood by flight deck personnel, and butyl knee patches to prevent tearing of the OG when flight deck personnel knelt down on a non-skid flight deck surface. These changes were made on the basis of NAEC's findings from tests of the UK MK III OG with the FD IPE. Butyl elbow patches were added by NCTRF, and patterns made from the NAEC hood design by NCTRF were used by NAEC to procure 16 modified CPOs for use in these tests. The FD IPE used was the cranial helmet, aural sound protectors, and MK-1 life vest. The CD IPE was the MCU-2/P protective mask, butyl gloves with cotton glove liners, and butyl footwear covers. The underclothing worn was the flight deck jersey, FRT cotton denim trousers, underwear shorts, wool socks, and flight deck boots. Tests were conducted at MOPP Level 4.

Test scenarios were:

Helicopter Launch and Recovery
Helicopter Maintenance
Aircraft Launch
Arresting Gear Remove/Replace
Aircraft Handling

METHODS AND PROCEDURES (Continued)

All test scenarios were first conducted with standard FD IPE to formulate baseline time data, and then with the modified CPOs and CD and FD IPE. Observer data sheets, test volunteer questionnaires, and video and still photography were used to evaluate compatibility issues. Prior to beginning the tests, the objectives were explained to the test volunteers, their body measurements were taken (sizing) and they were briefed on the CD clothing. For the CD exercises, the volunteers then don the modified CPOs and FD and CD IPE. Pictures were taken of each volunteer wearing the different OGs (front, back, bent knee, and bent elbow views), closeups of the mask/hood interface, and other compatibility areas. The volunteers did some simple movements (rotating their head, bending, squatting, etc.), and breaks in closures were noted.

Information to be recorded/observed for each test included:

Environmental Conditions (temperatures, wind speed, and RH)
Time to perform task
Physical manipulations required to performed task

Activities providing support for these tests were:

NAVSEA	-	Direct and Supervise Evaluation
NAEC	-	Monitor Evaluation (data collection and analysis); Provide Test Personnel; Support Equipment, Camera Coverage, and Test Modified CPOs
NCTRF	-	Assist in Monitoring Evaluation
CDTF, Ft. McClellan	-	CD Clothing Don/Doff Briefing, Provide CD IPE
NPRDC*	-	Observe Evaluation

* Naval Personnel Research and Development Center

The final physical compatibility tests related to flight deck operational scenarios were conducted during the OPDEMO with the ICPOs. These tests were also conducted at NAEC and involved aircraft handling and launching scenarios. Four (4) volunteers were dressed in an ICPO with either the 100% cotton or 50/50 polyester/cotton outer shell and UK G specification anti-gas cloth. The FD and CD IPE and underclothing were the same as used in the initial compatibility tests. NAEC and NCTRF personnel were involved in monitoring these tests.

METHODS AND PROCEDURES (Continued)

Physical and Simulated Chemical Agent Compatibility

The objective of these tests was to evaluate the physical compatibility of the prototype ICPO design with CD and FD IPE, and shipboard Contamination Control Area (CCA) procedures.

These tests were conducted by the NSWC on the two (2) ICPOs (cotton and polyester/cotton outer shells and UK G specification anti-gas cloth), and the UK MK III OG. The MCU-2/P and MK V masks were worn with the other CD IPE (butyl gloves with cotton glove liners and butyl footwear covers). The ICPOs were also tested with the cranial helmet. For the purposes of these tests, both ICPOs were treated as the same. Test procedures were as follows:

1. Personnel donned either the ICPO or the UK MK III OG, butyl gloves and footwear covers, the cranial helmet (only on some occasions with the ICPO), and either the MCU-2/P or MK V mask.

2. Recorded observations during the donning procedures.

3. Examined the mask/hood with and without the FD IPE, glove/sleeve cuff, footwear cover/leg cuff interfaces, and recorded observations.

4. Sprayed personnel with an agent stimulant*, front and back, at a concentration of approximately $5g/m^2$.

5. Processed personnel through a CCA using standard Navy shipboard CCA procedures.

6. Monitored processed personnel with a blacklight to identify any residual stimulant and recorded observations.

    * Stimulant - 99.9% Polyethylene Glycol-200 (PEG-200) and 0.1 Tinopal (Ultraviolet Tracer Dye).

METHODS AND PROCEDURES (Continued)

Five (5) personnel donned various combinations of OGs and masks, three (3) or four (4) times each, for a total of 16 individual OG/mask tests. The following reflects the various tests:

Test Number	Volunteer Number	OG	Mask	Flight Deck IPE	Sprayed
1	1	ICPO	MCU-2/P	No	Yes
2	2	ICPO	MK V	No	Yes
3	2	MK III	MCU-2/P	No	Yes
4	3	ICPO	MCU-2/P	Yes	Yes
5	4	ICPO	MCU-2/P	Yes	Yes
6	5	MK III	MCU-2/P	No	Yes
7	5	ICPO	MCU-2/P	Yes	Yes
8	4	ICPO	MCU-2/P	No	Yes
9	2	ICPO	MCU-2/P	Yes	Yes
10	3	ICPO	MCU-2/P	No	Yes
11	5	MK III	MCU-2/P	No	No
12	2	ICPO	MCU-2/P	No	No
13	1	ICPO	MCU-2/P	No	No
14	5	MK III	MK V	No	No
15	2	ICPO	MK V	No	No
16	1	ICPO	MK V	No	No

Operational Demonstration

The OPDEMO plan involved the evaluation of the ICPOs aboard different class ships (aircraft carrier, destroyer, amphibious warfare, etc.), and at different land based sites (Chemical Defense Training Facility (CDTF), Fort McClellan, Alabama, and Naval Construction Battalion Training Centers at Gulfport, Mississippi and Port Hueneme, California) to determine the suitability of their design in performing various operational functions that must be sustained in a chemical warfare environment by naval personnel (flight operations, damage control, amphibious landings of personnel and equipment, construction of facilities, etc.). The CDTF was to be used to obtain chemical agent wear data on the ICPOs by submitting worn garments to DPG representing 7, 14, 21, and 28 days of wear associated with performing pertinent training activities. This control effort to obtain chemical wear data did not occur, the CDTF only evaluated the ICPOs for physical characteristics.

The Persian Gulf conflict made it difficult for naval ship and shore units to support the OPDEMO because ships were undergoing accelerated refresher training pending assignment to the Persian Gulf, and shore base facilities were heavily involved in supporting Persian Gulf ship and land based needs. The aircraft carrier assigned to the program, the USS KENNEDY, was ordered to the Persian Gulf just before the OPDEMO was scheduled to begin. As a result, the information obtained from the OPDEMO from ship and shore units was essentially related to design factors.

Ships

Of the Naval ship units initially assigned to take part in the OPDEMO, only the USS JARRETT, FSG-33 and USS DULUTH, LPD-6 in San Diego, California; and the USS CONNOLLY, DD979 in Guantanamo Bay, Cuba were available for the conduct of CD exercises, where NCTRF personnel could board the ships to distribute the OGs and monitor the exercises.

USS JARRETT, FSG-33, and USS DULUTH, LPD-6[10]

NCTRF, NAEC, and NAVSEA personnel joined Fleet Support Group (FSG), San Diego, California instructors to evaluate the ICPOs. On each ship all personnel involved in repair locker training were split into groups according to locker assignment. All ship personnel then proceeded to their designated stations and awaited the call to General Quarters (GQ), MOPP Level 4. There were approximately three (3) FSG instructors, one (1) OPDEMO monitor, and 15 military personnel per locker. The JARRETT used two (2) lockers for the evaluation, and the DULUTH used three (3) lockers. Once GQ was called, ship ventilation systems were shut down, the hatches were secured, battle stations were manned, and the CD drill began.

Six (6) participants from each locker were dressed out in the ICPOs with three (3) wearing the FRT/WRT 100% cotton outer shell ICPOs and three (3) wearing the FRT/WRT 50/50% polyester/cotton ICPOs. The OGs had the UK G specification anti-gas cloth with and without the nylon scrim backing. The remaining participants wore the current CPO when necessary. Both ships were outfitted with only the MK V mask; one (1) MCU-2/P mask was borrowed from the FSG. The CD IPE; butyl gloves and cotton glove liners, and butyl footwear covers were worn with the OGs. During the CD drill, the participants were to simulate a chemical attack, dress out based on the particular MOPP level, as directed by the FSG, locate the contaminated areas, and identify the agent present. Upon completion of the exercise, the participants were debriefed with respect to the performance of the OGs.

USS CONNOLLY, DD979[11]

NCTRF personnel boarded the ship through arrangements made with FSG, Guantanamo Bay, Cuba. A briefing was held with the damage control assistant (DCA) and repair locker military personnel. It was agreed that three (3) people would be outfitted with previously worn ICPOs and instructed to keep them on while performing their normal duties. Masks, gloves, and footwear covers were not issued at this time. These ICPOs had been worn during previous shipboard testing, and used again to subject them to additional wear. The damage control parties would be required to don the ICPOs during the chemical attack drills. Participants from repair lockers 2 and 3 would be dressed and monitored by NCTRF personnel.

The repair parties were instructed to assemble topside to conduct chemical decontamination drills. GQ was called and two (2) of the participants wearing the worn OGs were assigned to repair 2 and one (1) to repair 3. Repair parties from both lockers were observed performing damage control, man overboard, and fire fighting drills until the establishment of MOPP Level 1. Activities of the repair locker parties were as follows:

Repair 2

MOPP 1	-	Chemical clothing and MCU-2/P masks issued. Masks were immediately donned. Four (4) additional participants were selected to wear the ICPOs. Repair parties continued to perform drills previously noted.
MOPP 2	-	CPOs and ICPOs were donned, hoods down.
MOPP 3	-	Participants outfitted in CPOs and ICPOs, footwear covers worn, gloves not worn, hood down.
MOPP 4	-	CD IPE fully donned with all fasteners secured and hood secured around mask.

METHODS AND PROCEDURES (Continued)

The participants conducted simulated chemical defense, fire fighting, and damage control drills in and around the spaces near the repair 2 area. Participants were monitored closely to protect them from becoming hyperthermic since they were working in an ambient condition of 90°F and 90% RH. Participants were asked periodically if they felt weak or dizzy, and all indicated they were fine.

Repair 3

Military personnel were issued a complete ensemble (mask, OG, gloves, and footwear covers). Participants began dressing out prior to MOPP 1. When all were completely dressed, the repair parties were divided into internal and external survey teams. The internal survey team did not participate in the drills because of a shortage of time. The external team participated in chemical defense, fire fighting, and damage control drills topside. The team was observed climbing ladders and coming through scuttle hatches. Participants were again monitored closely to guard against hyperthermia. The ambient temperature was 92°F and the RH was 90%. A M-256 agent detection kit was used in topside surveys to simulate the determination of a particular agent. After the CD drills were completed, participants were led to the mess deck to doff the OGs and to be debriefed.

Ships and Port Side Unit

For the other ships involved, the USS MOBILE, LKA-115 and USS CROMMELIN, FFG-37, San Diego, California, ICPOs and questionnaires were provided by NCTRF through the FTG, San Diego, California. For the port side unit, Amphib CB-1, Naval Air Station, Coronado, California, ICPOs and questionnaires were also provided by NCTRF through the FTG, San Diego, California.

Simulated Flight Deck and Land Based Site

For the simulated flight deck tests to be conducted at NAEC, and the land based tests to be conducted by the CDTF, Fort McClellan, Alabama, each organization received ICPOs and questionnaires directly from NCTRF.

A copy of the questionnaire form used by all participating organizations is provided in Appendix B.

RESULTS

Material Physical Properties

Outer Shell Materials

The physical properties of the outer shell materials for the current CPO (modacrylic/nylon) and the ICPO (cotton and polyester/cotton) are shown in Table II.

As can be seen, the modacrylic/nylon material was lighter than the candidate materials; had a higher breaking strength in the warp and filling directions; was stiffer than the cotton and had equal stiffness to the polyester/cotton in the warp direction, and was stiffer than the cotton and polyester/cotton in the filling direction; had better seam efficiency than the cotton (no result for the polyester/cotton); a lower water spray resistance than the cotton and polyester/cotton; a hydrostatic resistance which was equivalent to the cotton, and significantly greater than the polyester/cotton; and a higher air permeability than the cotton and polyester/cotton materials.

For the candidate materials: the cotton was lighter than the polyester/cotton; had equivalent breaking and greater tear strength in the warp and filling directions; was less stiff in the warp direction, and of equal stiffness in the filling direction; had greater abrasion resistance in the warp and filling directions; equal water spray resistance; significantly higher hydrostatic resistance; and significantly lower air permeability.

Anti-Gas Liner

The only physical test conducted on the anti-gas cloth liner materials, was abrasion resistance (FSTTM 5304). The UK F and G Specification materials, and the G Specification material with a nylon scrim laminated to the charcoal side of the fabric were abraded against the Navy's FRT 100% cotton chambray shirt material at a surface pressure of four (4) psi for 500 cycles. The materials were visually evaluated for penetration of the charcoal to the base cloth (loss of charcoal). The F Specification material showed substantial penetration to the base cloth, the G Specification material showed slight penetration to the base cloth, and the G Specification material with the nylon scrim showed no penetration to the base cloth.

Vertical Flammability Resistance

The vertical flammability resistance was similar for the cotton and polyester/ cotton ICPO outer shell materials, as indicated in Table III. The after flame and glow were less than 1.5 seconds, and the char length was less than 5.0 inches.

RESULTS (Continued)

TABLE II. Properties of Current and Candidate Outer Shell Materials

Characteristic	Material		
	FR/WRT Modacrylic/Nylon	FRT/WRT Cotton	FRT/WRT Poly/Cotton
Shade	Olive Drab	Green	Navy Blue
Blend (%)	70/30	100	50/50
Weave	Twill	Twill	Twill
Weight (oz/yd^2)	3.5	4.9	6.0
Ends/Inch	109	115	119
Picks/Inch	74	105	43
Break Strength (lbs.)			
Warp	142	103	123
Filling	106	68	63
Tear Strength (lbs.)			
Warp	-	6.7	3.9
Filling	-	5.6	3.2
Stiffness (in.lbs.)			
Warp	.004	.002	.004
Filling	.004	.001	.001
Seam Efficiency (%)	92	81	-
Abrasion Resistance (cycles)			
Warp	-	2557	1513
Filling	-	1619	963
Water Resistance, Spray Rating	80	100	100
Hydrostatic Resistance (cm.)	19	20	9
Air Permeability (ft.3/min/ft.2)	99	48	80

RESULTS (Continued)

TABLE III. Vertical Flammability Performance of Candidate Outer Shell Materials

Material	Weight (oz/yd^2)	After Flame (seconds)	After Glow (seconds)	Char Length (inches)
FRT/WRT, Cotton	4.9			
Warp		0.6	1.1	4.3
Filling		0.6	1.3	4.8
FRT/WRT Poly/Cotton	6.0			
Warp		0.0	1.4	4.9
Filling		0.0	1.4	4.1

Heat Protection

Radiant Heat Exposure

The heat transfer through the materials was similar for the cotton and polyester/cotton ICPO outer shell materials, as shown in Table IV. The peak heat flux transferred through the fabrics was identical without the anti-gas cloth, and higher for the polyester/cotton with the anti-gas cloth, and higher for the polyester/cotton with the anti-gas cloth. Estimated time to burn injury was equal for the outer shell materials when tested alone (15 seconds); and higher for the cotton - anti-gas cloth assembly, 35 versus 31 seconds for the polyester/cotton - anti-gas cloth assembly.

Convective and Radiant Heat Exposure

The heat energy transferred through the outer shell materials was similar, as shown in Table V. Estimated time to burn injury was four (4) seconds for the outer shells tested alone. For the cotton and polyester/cotton anti-gas cloth assemblies, the heat energy transferred through the polyester/cotton assembly was higher than the cotton assembly (Table V), estimated time to burn injury was ten (10) seconds for the cotton assembly and nine (9) seconds for the polyester/cotton assembly. The charcoal in the anti-gas cloth had an after glow in the polyester/cotton assembly test.

RESULTS (Continued)

TABLE IV. Radiant Heat Exposure of Candidate Outer Shell Materials, with and without the G Specification Anti-Gas Cloth Liner, at a Heat Flux of 0.5 g cal/cm^2/sec

Outer Shell	Anti-Gas Cloth	Peak Heat Flux (g cal/cm^2/sec)	Time to Burn Injury (sec.)
FRT/WRT, Cotton	No	0.24	15.0
	Yes	0.15	35.0
FRT/WRT Poly/Cotton	No	0.24	15.0
	Yes	0.17	31.0

TABLE V. Convective/Radiant Heat Exposure of Candidate Outer Shell Materials, with and without the G Specification Anti-Gas Cloth Liner, at a Heat Flux of 2.0 g cal/cm^2/sec

Outer Shell	Condition	Heat Energy Tranferred (g cal/cm^2)	Time to Burn Injury (sec.)	Note
FRT/WRT Cotton	Spacer, 0.25 in.	8.0	4.0	
	Anti-Gas Cloth	18.6	10.0	
FRT/WRT Poly/Cotton	Spacer, 0.25 in.	8.2	4.0	
	Anti-Gas Cloth	20.2	9.0	AGCS

AGCS - After Glow Charcoal Side

RESULTS (Continued)

Flame Envelopment Tests

The fuel fire pit test results are depicted in Table VI. For the current CPO, modacrylic/nylon outer shell, UK F Specification liner, no burn injury occurred in the three (3) test runs. The heat flux ranged from 2.2 to 2.6 g cal/cm^2/sec. However, there was considerable after flame in two (2) of the three (3) tests (heat flux 2.6 g cal/cm^2/sec), and when the after flame time reached 30 seconds a fire extinguisher was needed to quench the flames. The modacrylic/nylon outer shell material had completely melted and the charcoal in the anti-gas cloth was glowing. If this flaming was allowed to continue the entire OG would have burnt, causing significant burn injury.

In three (3) tests of the cotton ICPO, the heat flux ranged from 1.7 to 3.1 g cal/cm^2/sec. In the test with the highest heat flux (3.1 g cal/cm^2/sec), a burn injury of 3.5% of total body area occurred in one (1) armpit area. The after flame time had reached 32 seconds in this area of the OG, when the flames were quenched with a fire extinguisher. In the other two (2) runs at the lower heat fluxes, there was no body burn injury. In the test having a heat flux of 2.6 g cal/cm^2/sec, the after flame time was two (2) seconds.

For the polyester/cotton ICPO, the heat flux ranged from 2.1 to 3.4 g cal/cm^2/sec in the three (3) tests conducted. No body burn injury occurred in any of these tests. In the test where the heat flux was 3.4 g cal/cm^2/sec there was a four (4) second after flame.

The requirement for this type of fire exposure is less than 20% body area burn injury at a heat flux level of 2.0 g cal/cm^2/sec for a two (2) second exposure period, or a total heat exposure of 4.0 g cal/cm^2. In those tests where burn injury occurred with one of the cotton OGs, and where after flame time was excessive in two (2) of the tests with the modacrylic/nylon OG, and in one test with a cotton OG, the total heat energy exposure exceeded the requirement. For the modacrylic/nylon OG, the total heat energy exposure was 5.2 g cal/cm^2 in the two (2) tests where significant after flame occurred. In the cotton OG test, where burn injury and significant after flame occurred, the total heat energy exposure was 6.2 g cal/cm^2.

Without consideration of the requirement, the polyester/cotton OGs performed best. The total heat energy exposure in one test was 6.8 g cal/cm^2, and no burn injury or significant after flame occurred.

RESULTS (Continued)

TABLE VI. Flame Envelopment tests of Current and Interim Chemical Protective Overgarments

Outer Shell	Anti-Gas Liner	Heat Flux (g cal/cm^2/sec)	Run Time (sec)	Body Burn Area (%)	After Flame (sec)
Modacrylic/	F Specification	2.6	2	0	30*
Nylon	F Specification	2.6	2	0	30*
	F Specification	2.2	2	0	0
FRT/WRT	G Specification	2.6	2	0	2
Cotton	G SPecification	3.1	2	3.5**	32**
	G Specification with Nylon Scrim	1.7	2	0	0
FRT/WRT	G Specification	2.7	2	0	0
50/50%	G Specification	2.1	2	0	0
Poly/Cotton	G Specification with Nylon Scrim	3.4	2	0	4

* Although no body burn injury occurred there was significant after flaming of the modacrylic-nylon overgarment. The modacrylic-nylon outer shell material completely melted in these fire tests, directly exposing the anti-gas cloth to the fire.

** A high heat flux of 3.1 g cal/cm^2/sec caused burn through of all layers of the FRT cotton overgarment and under clothing in one armpit area. The burning and smoldering of the anti-gas charcoal layer in this area resulted in a 32 second after flame and a 3.5% body area burn injury.

RESULTS (Continued)

Biophysical Evaluation

The chemical insultaion (CLO) and water vapor permeability (Im) test results on the current CPO and the ICPO conducted on the NCTRF thermal manikin are provided in Table VII. There were minimal differences in the data between the OGs at MOPP Levels 3 and 4. However, the differences in Im, and the Im/CLO values were significant between MOPP Levels 3 and 4 for each OG. For all OGs the Im values were 0.15 to 0.17 higher, and the Im/CLO values 0.1 higher for the MOPP 3 level compared to MOPP 4. The change in the Im/CLO values between MOPP Levels 3 and 4 represents a 56-63% increase in the amount of body heat that can be dissipated at MOPP Level 3 compared to MOPP Level 4.

TABLE VII. Thermal Insulation (CLO) and Water Vapor Permeability (Im) Tests of Current and Interim Chemical Protective Overgarments

Overgarment	MOPP Level	CLO	Im	Im/CLO
Modacrylic/Nylon Outer Shell, UK F	3	2.0	0.51	0.26
Specification Liner	4	2.2	0.36	0.16
FRT/WRT, Cotton Outer Shell, UK G	3	2.0	0.54	0.27
Specification Liner	4	2.2	0.37	0.17
FRT/WRT Poly/Cotton Outer	3	1.9	0.54	0.28
Shell, UK G Specification Liner	4	2.1	0.37	0.18

Physiological Evaluation

Physiological tests of the current CPO, modacrylic/nylon outer shell, UK F Specification anti-gas cloth liner; and two (2) ICPOs, with cotton and polyester/cotton outer shells and UK G Specification anti-gas cloth liners were conducted in a hot-dry (49°C, 20% RH, and 2.2 m/s wind) and hot-humid (35°C, 75% RH, and 4.5 m/s wind) environment at MOPP Level 4, with a moderate work rate (300 watts). The results were as follows:

RESULTS (Continued)

Tolerance Time - There were no statistically significant differences in tolerance time when any of the three (3) OGs was worn in either of the two (2) environments ($p > 0.05$). In the hot-dry environment, average tolerance time was 77 minutes (range 59-90 minutes) for the current CPO, 70 minutes (range 50-90 minutes) for the cotton ICPO, and 71 minutes (range 50-94 minutes) for the poly/cotton ICPO. In the hot-humid environment, average tolerance time was 101 minutes (range 78-150 minutes) for the current CPO, 87 minutes (56-162 minutes) for the cotton ICPO, and 101 minutes (70-180 minutes) for the poly/cotton ICPO.

Change in Rectal Temperature - In the hot-dry environment, there was no significant differences in the rectal temperature response among the three (3) OGs ($p > 0.05$). Increase in rectal temperature after 60 minutes of heat exposure averaged 1.6°C, 1.6°C, and 1.4°C for the cotton ICPO, poly/cotton ICPO, and current CPO, respectively. In the hot-humid environment, there were also no significant differences in the rectal temperature response among the three (3) OGs for the first 60 minutes of heat exposure ($p > 0.05$). At 70 minutes, the increase in rectal temperature for the cotton ICPO was greater than for the current CPO and poly/cotton ICPO ($p < 0.05$). After 70 minutes of heat exposure, the increase in rectal temperature averaged 1.5°C, 1.4°C, and 1.3°C for the cotton ICPO, poly/cotton ICPO, and current CPO, respectively.

Mean Weighted Skin Temperature - There were no significant differences in mean weighted skin temperature among the three (3) OGs in either the hot-dry or hot-humid environment. In the hot-dry environment, mean weighted skin temperature after 60 minutes of heat exposure averaged 38.3°C for all three (3) OGs. In the hot-humid environment, mean weighted skin temperature after 70 minutes of heat exposure averaged 37.8°C, 37.3°C, and 37.2°C for the cotton ICPO, the poly/cotton ICPO, and the current CPO, respectively.

Heart Rate - There were no differences in heart rate response among the three (3) OGs in either of the environments. In the hot-dry environment, heart rate after one (1) hour averaged 170, 162, and 153 beats/minutes for the poly/cotton ICPO, cotton ICPO, and current CPO, respectively. After one (1) hour in the hot-humid environment, heart rate averaged 165, 153, and 153 beats/minute for the cotton ICPO, poly/cotton ICPO, and the current CPO, respectively.

Sweating Rate - There were no significant differences in total body sweating rate among the three (3) OGs in either of the two (2) environments. In the hot-dry environment, sweating rate averaged 918, 838, and 820 $g/m^2/h$ for the poly/cotton ICPO, cotton ICPO, and the current CPO, respectively. In the hot-humid environment, sweating rate averaged 871, 864, and 813 $g/m^2/h$ for the current CPO, cotton ICPO, and poly/cotton ICPO, respectively.

RESULTS (Continued)

Summary - For the hot-dry and hot-humid environments, there were no significant differences in the level of heat strain caused by the current CPO and the two (2) ICPOs. This was demonstrated by similar tolerance times for the three (3) OGs, as well as similar rectal temperature, skin temperature, heart rate, and sweating rate responses. (One (1) exception was a statistically higher rectal temperature for the cotton ICPO, compared to the poly/cotton ICPO and the current CPO at the end of the hot-humid heat exposure). When any of the three (3) OGs were worn, volunteers performing moderate exercise were not able to complete the three (3) hour exposure in either environment. In the hot-dry environment, average tolerance time was 73 minutes. In the hot-humid environment, average tolerance time was 96 minutes.

Chemical Agent Tests

Chemical agent test results for new ICPO materials are shown in Tables VIII and IX, and in Tables X and XI for worn ICPO materials.

New Materials - For the HD L/V tests with new materials (Table VIII), two (2) 1 mg agent droplets were applied at the start of a test and at eight (8) hour intervals thereafter. The minimum breakthrough time was 16 hours with the UK F Specification liner with all three (3) outer shell materials (modacrylic/nylon, cotton, and polyester/cotton). For the UK G Specification liner, the minimum breakthrough time was 16 hours with the cotton outer shell, 24 hours with the modacrylic/nylon outer shell, and 32 hours with the polyester/cotton outer shell. With the nylon scrim bonded to the UK G Specification liner, the minimum breakthrough time was 32 hours with all three (3) outer shell materials.

In the HD V/V tests with new materials (Table IX), the HD vapor contamination level was 20 $\pm$ 2 micrograms/liter. For the UK F Specification liner, the minimum breakthrough time was less than eight (8) hours with the polyester/cotton outer shell, eight (8) hours with the cotton outer shell, and 16 hours with the modacrylic/nylon outer shell. For the UK G Specification liner, the minimum breakthrough time was 16 hours with all three (3) outer shell materials. With the nylon scrim bonded to the UK G Specification liner, the minimum breakthrough time was eight (8) hours with the modacrylic/nylon outer shell, and 16 hours with the cotton and polyester/cotton outer shells.

RESULTS (Continued)

TABLE VIII. HD Liquid Challenge/Vapor Penetration Tests of New Interim Chemical Protective Overgarment Materials

Material Composite: Activated Charcoal Liner	Material Composite: Outer Shell	Minimum Breakthrough Time (hours)
UK F Specification	Modacrylic/Nylon	16
UK F Specification	FRT/WRT 100% Cotton	16
UK F Specification	FRT/WRT 50/50% Poly/Cotton	16
UK G Specification	Modacrylic/Nylon	24
UK G Specification	FRT/WRT 100% Cotton	16
UK G Specification	FRT/WRT 50/50% Poly/Cotton	32
UK G Specification with Nylon Scrim	Modacrylic/Nylon	32
UK G Specification with Nylon Scrim	FRT/WRT 100% Cotton	32
UK G Specification with Nylon Scrim	FRT/WRT 50/50% Poly/Cotton	32

Two 1 mg drops were applied at 0, 8, 16, 24, 32, and 40 hours.

Worn Overgarment Materials

For the HD L/V tests with worn OG materials (Table X), two (2) 1 mg agent droplets were applied at the start of a test and at eight (8) hour intervals thereafter. The minimum breakthrough time for the UK F Specification liner was 32 and 24 hours for the shirt and trousers components, respectively, with the modacrylic/nylon outer shell. For the UK G Specification liner, the minimum breakthrough time was 24 and 32 hours for the shirt and trousers components, respectively, with the cotton outer shell, and 24 hours for the shirt and trousers components, with the polyester/cotton outer shell. With the nylon scrim bonded to the UK G Specification liner, the minimum breakthrough time was 16 and 24 hours for the shirt and trouser components, respectively, with the cotton outer shell, and 32 hours for the shirt and trousers components, respectively, for the polyester/cotton outer shell.

RESULTS (Continued)

In the HD V/V tests with worn OG materials (Table XI), the HD vapor contamination level was 20 $\pm$ 2 micrograms/liter. For the UK F Specification liner, the minimum breakthrough time was eight (8) hours for the shirt and trousers components, with the modacrylic/nylon outer shell. For the UK G Specification liner, the minimum breakthrough time was eight (8) and 24 hours for the shirt and trousers components, respectively, with the cotton outer shell, and 16 hours for the shirt and trousers components, with the polyester/cotton outer shell. With the nylon scrim bonded to the UK G Specification liner, the minimum breakthrough time was eight (8) hours for the shirt and trousers components, with the cotton outer shell, and 24 and eight (8) hours for the shirt and trousers components, respectively, with the polyester/cotton outer shell.

TABLE IX. HD Vapor Contamination/Vapor Penetration Tests of New Interim Chemical Protective Overgarment Materials

Material Composite		Minimum
Activated Charcoal Liner	Outer Shell	Breakthrough Time (hours)
UK F Specification	Modacrylic/Nylon	16
UK F Specification	FRT/WRT 100% Cotton	8
UK F Specification	FRT/WRT 50/50% Poly/Cotton	<8
UK G Specification	Modacrylic/Nylon	16
UK G Specification	FRT/WRT 100% Cotton	16
UK G Specification	FRT/WRT 50/50% Poly/Cotton	16
UK G Specification with Nylon Scrim	Modacrylic/Nylon	8
UK G Specification with Nylon Scrim	FRT/WRT 100% Cotton	16
UK G Specification with Nylon Scrim	FRT/WRT 50/50% Poly/Cotton	16

Vapor Contamination Level was 20 $\pm$ 2 micrograms/liter

RESULTS (Continued)

TABLE X. HD Liquid Challenge/Vapor Penetration Tests of Worn Interim Chemical Protective Overgarment Materials

OG	Material Composite: Activated Charcoal Liner	Material Composite: Outer Shell	Minimum Breakthrough Time (hours)
1S*	UK F Specification	Modacrylic/Nylon	32
1T**	UK F Specification	Modacrylic/Nylon	24
2S	UK G Specification	FRT/WRT 100% Cotton	24
2T	UK G Specification	FRT/WRT 100% Cotton	32
4S	UK G Specification	FRT/WRT 50/50% Poly/Cotton	24
4T	UK G Specification	FRT/WRT 50/50% Poly/Cotton	24
3S	UK G Specification with Nylon Scrim	FRT/WRT 100% Cotton	16
3T	UK G Specification with Nylon Scrim	FRT/WRT 100% Cotton	24
5S	UK G Specification with Nylon Scrim	FRT/WRT 50/50% Poly/Cotton	32
5T	UK G Specification with Nylon Scrim	FRT/WRT 50/50% Poly/Cotton	32

Two (2) 1 mg drops were applied at 0, 8, 16, 24, 32, and 40 hours.

* 1S - Smock for Number 1 Overgarment (OG), typical
** 1T - Trouser for Number 1 Overgarment (OG), typical

RESULTS (Continued)

TABLE XI. HD Vapor Contamination/Vapor Penetration Tests of Worn Interim Chemical Protective Overgarment Materials

	Material Composite		Minimum
OG	Activated Charcoal Liner	Outer Shell	Breakthrough Time (hours)
1S*	UK F Specification	Modacrylic/Nylon	8
1T**	UK F Specification	Modacrylic/Nylon	8
2S	UK G Specification	FRT/WRT 100% Cotton	8
2T	UK G Specification	FRT/WRT 100% Cotton	24
4S	UK G Specification	FRT/WRT 50/50% Poly/Cotton	16
4T	UK G Specification	FRT/WRT 50/50% Poly/Cotton	16
3S	UK G Specification with Nylon Scrim	FRT/WRT 100% Cotton	8
3T	UK G Specification with Nylon Scrim	FRT/WRT 100% Cotton	8
5S	UK G Specification with Nylon Scrim	FRT/WRT 50/50% Poly/Cotton	24
5T	UK G Specification with Nylon Scrim	FRT/WRT 50/50% Poly/Cotton	8

Vapor Contamination Level was 20 $\pm$ 2 micrograms/liter.

* 1S - Smock for Number 1 Overgarment (OG), typical

** 1T - Trouser for Number 1 Overgarment (OG), typical

RESULTS (Continued)

Compatibility Tests

Physical Compatibility

The physical compatibility tests with the modified CPO were conducted at NAEC, where simulated flight deck operations covering helicopter maintenance, aircraft handling, helicopter launch and recovery, arresting gear, and aircraft launch were conducted. Environmental conditions during these operations were:

Operation	Sky Condition	Temperature (^oF)	Relative Humidity (%)	Wind (K)
Helicopter	Inside	72	75	0
Aircraft Handling	Partly Sunny	53	43	12
Helicopter Launch and Recovery	Partly Sunny	59	34	11
Arresting Gear	Sunny	61	38	2
Aircraft Launch	Sunny	65	63	12

NOTE: The minimum and maximum times to conduct these operational scenarios in the modified CPO, were 1 to 3.5 minutes.

Twenty (20) volunteers took part in these tests. Their responses to the questionnaires provided are indicated in Table XII. A summary of the anecdotal comments from the volunteers are provided in Table XIII, and a complete text of their comments in Appendix C1.

Based on the Table XII data, most volunteers (75% or more) thought the modified CPO was easy to don; easier to adjust fit; that there were no compatibility problems with the chemical gloves and footwear covers, MCU-2/P mask, cranial helmet, and life vest; closures were easy to use; the CPO did not irritate their skin; comfort was fair to excellent; the location, size, and accessibility of pockets was satisfactory; freedom of movement was good to excellent; and no damage occurred to the CPO. Fifty five percent (55%) and 78% experienced component problems and temperature discomfort, respectively, and 60-69% thought that the fit of the modified CPO was average to good, that they were able to perform their duties, that there were no safety related problems, and preferred the modified CPO to the current CPO.

RESULTS (Continued)

The summary data provided in Table XIII indicate, that of 82 responses regarding the modified CPO and the IPE worn, 77 were negative and 5 positive. Most of the negative responses (58), were associated with the hood (23), mask (15), footwear cover), and gloves (6). The positive responses (5) were related to fit (1), mob. (2), mask (1), and no problems (1).

Of 19 responses concerning the best feature of the modified CPO, 14 related to the fasteners (2), fit (3), lightweight (2), and mask drinking tube (2), smock (3), and trousers (2). Of 20 responses concerning the worst features of the modified CPO, 14 related to the hood (2), footwear covers (5), ability to perform duties (2), mask (3), and hot (2).

Of the 19 responses regarding improvements needed, 12 were concerned with nothing (3), footwear covers (6), and the mask (3). There were no responses regarding preference for the modified CPO versus the CPO.

TABLE XII. Physical Compatibility Questionnaire Data for Simulated Flight Deck Operations Conducted at NAEC with the Modified NAEC CPOs

Characteristic			Number of Responses	Average (%)
Donning				
	Easy	Yes	17	85
	Difficult	Yes	3	15
Adjusting Fit				
	Easy	Yes	15	75
	Difficult	Yes	5	25
Compatibility Problems				
Gloves		Yes	3	15
		No	17	85
Footwear Covers		Yes	3	15
		No	17	85
MCU-2/P Mask		Yes	2	10
		No	18	90

RESULTS (Continued)

TABLE XII. Physical Compatibility Questionnaire Data for Simulated Flight Deck Operations Conducted at NAEC with the Modified NAEC CPOs (Continued)

Characteristic			Number of Responses	Average (%)
Cranial Helmet		Yes	5	25
		No	15	75
Life Vest		Yes	0	0
		No	20	100
Component Problem		Yes	9	45
		No	11	55
Closure Usage				
	Easy	Yes	19	100
	Difficult	Yes	0	0
Skin Problems		Yes	2	10
		No	18	90
Experienced Discomfort, Temperature Conditions		Yes	14	78
		No	4	22
Fit of Modified CPO				
	Average to Good	Yes	12	60
	Marginal to Poor	Yes	8	40
Comfort of Modified CPO				
	Fair to Excellent	Yes	16	80
	Marginal	Yes	4	20

RESULTS (Continued)

TABLE XII. Physical Compatibility Questionnaire Data for Simulated Flight Deck Operations Conducted at NAEC with the Modified NAEC CPOs (Continued)

Characteristic			Number of Responses	Average (%)
Adequacy of Pockets				
	Location	Yes	16	100
		No	0	0
	Accessibility	Yes	15	100
		No	0	0
	Size	Yes	15	100
		No	0	0
Freedom of Movement				
	Good to Excellent	Yes	15	75
	Marginal to Poor	Yes	5	25
Able to Perform Duties:		Yes	12	63
Helicopter Maintenance; Launch and Recovery; and Moving and Chaulking Aircraft		No	7	37
Safety Related Problems		Yes	4	31
		No	9	69
Any Damage to Modified CPO		Yes	0	0
		No	20	100
Overall Preference for the Modified CPO Versus the CPO		Yes	8	67
		No	4	33

RESULTS (Continued)

TABLE XIII. **Summary of Physical Compatibility Questionnaire Comments for Simulated Flight Deck Operation Conducted at NAEC with the Modified Chemical Protective Overgarments**

Item	Comments	
	Positive	Negative
Hood	-	23
Trousers	-	3
Fasteners	-	3
Pockets	-	1
Fit	1	-
Donning	-	1
Mobility	2	-
Hot	-	3
Mask	1	15
Footwear Covers	-	14
Gloves	-	6
Training	-	1
Sleeve/Glove Interface	-	1
Cranial Helmet	-	3
Cranial/Mask	-	2
Weight	-	1
No Problems	1	-
TOTAL	5	77

RESULTS (Continued)

TABLE XIII. **Summary of Physical Compatibility Questionnaire Comments for Simulated Flight Deck Operation Conducted at NAEC with the Modified Chemical Protective Overgarments (Continued)**

Best Feature	# of Resp.	Worst Feature	# of Resp.	Improvements Needed	# of Resp.
Fasteners	2	Hood	2	Nothing	3
Hood/Vest	1	Size of Trousers	1	Hood	2
Doffing	1	Footwear Covers	5	Better Fit	1
Lightweight	2	Donning	1	Footwear Covers	6
Mobility	1	Mobility	1	Gloves	1
Mask		Performing Duties	2	Rainproof and Windproof	1
- Drinking Tube	2	Mask	3	Easier Donning	1
- Lens	1	Mask/Hood/Cranial	1	Make Cooler	1
Smock	3	Mask Looking Into Sun	1	Mask	
Trousers	2	Hot	2	- Tinted Lens	1
Foot Covers	1	Glove	1	- Better Breathing	1
Fit	3			- Allow for Wearing Eyeglasses	1
TOTAL	19	TOTAL	20	TOTAL	19

Preference, Modified CPO versus CPO - No Comments

Physical and Simulated Chemical Agent Compatibility

The ICPO was evaluated at NSWC, Dahlgren, Virginia for physical compatibility and simulated agent protection with CD and FD IPE, and to determine the influence of the ICPO design on shipboard CCA procedures. The two (2) candidate ICPOs, cotton and polyester/cotton outer shells with the UK G Specification liner were treated as one (1) OG in these tests because of their physical similarity. The only notable difference was the greater stiffness of the polyester/cotton outer shell material. The current CPO was also tested, and the two (2) Navy masks, the MK V and MCU-2/P, were both used in determining their compatibility with the current CPO and the ICPO. There were 16 tests involving different configurations. These different configurations included the wearing of both masks with the current CPO and the candidate ICPOs. In ten (10) of these configurations the OGs were sprayed with a chemical simulant to determine the adequacy of the interface closures in preventing the penetration of the simulant to the inside of the OG (see the Methods and Procedures section under this topic for the test matrix).

ICPO and MCU-2/P Mask Interface (Without Cranial)

There were six (6) tests employing this configuration. In four (4) of these tests, the agent simulant was used to determine penetration into the OG. Difficulties were found in obtaining a good seal in the head/neck area because of excess material around the circumference of the mask/hood interface, which "bunches up" at the zipper area, creating a poor seal. The drawstring was also difficult to adjust. A buddy was required to tighten the drawstrings because of their placement and securing mechanisms. Even with a buddy, it took in the order of minutes to get the best seal possible with the drawstrings. An average person could not properly adjust the drawstrings without help.

The seals obtained at the sleeve/glove and trousers/footwear cover interfaces were good. The waist drawstring also provided a good seal, but the hanging drawstrings may cause a snagging problem aboard ship.

In only two (2) of four (4) tests, where volunteers were sprayed with agent simulant, were they monitored for simulant penetration after CCA processing. They were found clean (no traces of dye were found on their underclothing or skin).

ICPO and MCU-2/P Mask Interface (With Cranial)

There were three (3) tests employing this configuration. This combination indicated a poor fit between the ICPO hood and the cranial helmet because the enlarged hood was too small. Observations showed large open gaps near each ear and a poor fit in the forehead area. An increase in circumference of about two (2) inches is needed at the hood/mask interface. In one (1) test, there was a fairly good fit. Monitoring for simulant penetration after CCA processing, showed no agent simulant penetration.

RESULTS (Continued)

ICPO and MK V Mask Interface

There were three (3) tests employing this configuration. In each test with this combination, the hood was pulled down over the mask lens area, the tighter the drawstring was pulled. With this mask/hood combination, the drawstring has nothing to secure to, resulting in a very poor seal. In all tests, the small protrusions on the MK V mask in the forehead area were too small for the ICPO drawstring to secure onto. Spraying with simulant was only performed in one (1) test, and the results were inconclusive because the volunteer was not monitored prior to CCA processing.

Current CPO (MK III) and MCU-2/P Mask Interface

There were three (3) tests employing this configuration. This combination had been previously tested and found suitable, providing use of FD IPE is not required.

In all tests, there was a good initial fit, but extreme neck and arm stretching caused gaps at the mask/hood interface in the lower chin and ear areas. When stretching ceased, the gaps were no longer visible. CCA processing was done in two (2) tests, one OG was clean while the other indicated penetration at the left inner wrist and back left shoulder.

Current CPO and MK V Mask Interface

There was only one (1) test with this configuration. This combination had been previously tested and found suitable, providing use of FD IPE is not required.

There was a good initial fit, but extreme neck and arm stretching revealed a gap at the hood/mask interface in the lower chin area while stretching.

Summary

The candidate ICPOs were:

1. Incompatible with the MCU-2/P mask because of gaps at the hood/mask interface.

2. Incompatible with all cranial helmet sizes because the hood volume was insufficient.

3. Incompatible with the MK V mask because the drawstrings have nothing to secure to, resulting in a poor seal.

4. Compatible with the butyl gloves and footwear covers.

5. Compatible with shipboard CCA processing procedures; no simulant contamination was found in any of the processing tests.

Modifications to the ICPO are required to increase user friendliness and decrease donning time. The hood's drawstring design is the main problem regarding the poor hood/mask interface. The waist drawstring may cause snagging problems and should be redesigned.

Operational Demonstration

Ships

USS JARRETT, FSG-33, and USS DULUTH, LPD-6

Twelve (12) damage control personnel from two (2) lockers on the JARRETT, and 18 from three (3) lockers on the DULUTH, wore the ICPOs while conducting a chemical defense drill on each ship at MOPP Level 4. Fifteen (15) wore an ICPO with the cotton outer shell and UK G Specification liner, and 15 wore an ICPO with the polyester/cotton outer shell and UK G Specification liner. Some of the liners had a nylon scrim bonded to the charcoal side. Other personnel participating wore the current CPO. Based on the observations of the OPDEMO monitors and FTG personnel, the following was noted:

1. The hood/mask interface was not secure with the MK V mask. When the cranial helmet is not worn, there is excess hood material, causing the hood to fall over part of the mask lens. The hood/mask interface was somewhat better with the MCU-2/P mask. The enlarged hood requires a means of taking up the excess material when the cranial helmet is not worn, such as hook and loop tabs at the back of the hood.

2. The hook and loop tapes at the wrist do not allow the sleeve to tighten around the glove sufficiently. The sizing of the tapes needs to be changed.

3. Personnel involved in these tests felt the ICPOs were heavier than the current CPO, particularly the ICPO with the polyester/cotton outer shell. The cotton and polyester/cotton outer shells are heavier than the modacrylic/nylon outer shell used with the current CPO, the polyester/cotton being the heaviest.

4. Participants questioned the use of the butyl knee and elbow patches, since

they contributed to the OG's weight and stiffness. Using an additional layer of the ICPO outer shell material instead of the butyl patches may improve this condition, while preventing damage to the suit in these areas.

5. FTG personnel were concerned that for topside personnel under sunny conditions, the dark colors of the ICPOs (green and navy blue) would contribute to heat stress. The planned color for the ICPO was olive drab because this is a joint service, universally accepted color. Other colors will be considered.

6. FTG personnel were concerned that the atropine and two (2) M-Chloride injectors may not be able to penetrate the new materials. The anti-gas cloth with the nylon scrim laminate may make needle penetration even more difficult.

7. New doffing procedures may be appropriate with the zipper front opening of the smock. Cutting the waist drawstring with the scissors currently available at decontamination stations is not possible. Surgical scissors did work. Participants were asked to doff the smock without contaminating their underclothing. If an assistant rolled the smock up and off the back while the participant leaned over with arms extended, it seemed that no contamination would occur.

8. Due to elevated temperatures in the locker areas, several participants felt dizzy and were told to sit down. One volunteer did faint due to the high temperatures while wearing the current CPO.

USS CONNOLLY, DD979

Seven (7) damage control personnel wearing the ICPOs conducted a chemical defense drill at MOPP Level 4. Other ship personnel participating in the drill wore the current CPO. All participants wore the MCU-2/P mask, and all activities were performed topside. The air temperature was 90°F and the RH was 90%. Based on the observations of the monitors and participant input, the following were identified as problem areas:

1. Inadequate hood/mask interface. This may have been partially caused by the oversize OG worn by some participants.

2. Difficulty in obtaining an adequate seal at the sleeve/glove and trousers/footwear cover interfaces because of the positioning of the hook and loop tapes.

3. Improper positioning of the hook and loop tapes on the modified hoods. Difficulty was experienced in adjusting the fit of the hood and keeping the hook and loop closures sealed.

4. Leg hook tabs can be torn off with little more than normal exertion. One (1) participant tore a hook tab while removing the trousers.

5. Charcoal without the protective scrim bleeds easily when wet from sweating, staining underclothing.

6. One participant was concerned that a smock with a zipper would not provide an adequate seal to protect against chemical agents.

7. Several other participants indicated that although they preferred the ICPO to the current CPO, they felt that their needs would be better satisfied with a coverall style OG with attached booties.

Ships and Port Side Unit

The USS Mobile, LKA-115, and the USS CROMMELIN, FFG-37 were involved in conducting shipboard chemical defense drills, and Amphib CB-1, Naval Air Station, Coronado, California was involved in conducting port side chemical defense drills.

Twenty-one (21) military personnel participated in these tests. Personnel data and responses to the questionnaire are provided in Tables XIV and XV, and a summary of anecdotal comments from the participants are shown in Table XVI. A complete text of their comments are provided in Appendix C2.

Personnel data, Table XIV, indicate that the participants ranged in age from 19-38, height from 5 feet 2 inches to 6 feet 2 inches, and weight from 130-235 lbs. As noted in the table, it appears that four (4) people provided a medium size OG should have been issued a large size, and two (2) people provided a medium size OG should have been issued a small size. The duties conducted during the evaluation are also shown, ranging from driving a boat to operating a forklift truck for Amphib CB-1, and conducting agent detection and decontamination exercises on USS MOBILE and USS CROMMELIN.

Based on Table XV data, the ICPOs were worn for less than two (2) hours. Participant responses to questions indicate that 75% or more thought that adjusting fit was easy; there were no compatibility problems regarding the gloves, footwear covers, and MCU-2/P mask; did not experience skin problems; fit was average to

RESULTS (Continued)

good; pockets were adequate with respect to location, accessibility, and size; freedom of movement was good to excellent; able to perform duties; had no safety related problems; no damage to the ICPO; and preferred the ICPO to the current CPO. Two (2) of four (4) participants from Amphib CB-1 had donning problems, while 78-88% on the MOBILE and CROMMELIN, respectively had no donning problems. 44%, 50%, and 57% on the MOBILE, Amphib CB-1, and CROMMELIN, respectively had component problems, 33% on the MOBILE had closure usage problems, and 62% on the CROMMELIN had temperature discomfort.

TABLE XIV. Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Personnel Data

Location/ Ship	Name	Rank/ Rate	Station/ Duties	Age (yrs)	Height ft.	Height in.	Weight (lbs)	Size Worn
Amphib CB-1	Trinidad, EE	Bosun Mate	Drove Boat	38	5	2	155	Sm
Amphib CB-1	Stevens	EN3 E-4	Engine Room and Line Handling	22	5	6	170	Med
Amphib CB-1	Fode, WL	ACB-1, A Co. 2nd Plt.	Mechanic Work on Equipment	20	5	7	150	Med
Amphib CB-1	Rolle, M.	CMCA	Forklift Work	18	6	0	235	*Med
USS MOBILE, LKA-115	Rebut, WK	SnBn	Agent Detector Exercise, Repair 3	21	6	2	185	Lrg
USS MOBILE, LKA-115	Dennis, SA	-	Scrubbed Chemical from Deck	20	5	8	-	-
USS MOBILE, LKA-115	Etheridge	E-4, DC-3	Agent Detector Exercise, Main and Flight Deck	22	5	11	158	-

RESULTS (Continued)

TABLE XIV. Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Personnel Data (Continued)

Location/ Ship	Name	Rank/ Rate	Station/ Duties	Age (yrs)	Height ft.	in.	Weight (lbs)	Size Worn
USS MOBILE, LKA-115	Sellers	E-4, ABH-3	Plugman	24	5	10	160	-
USS MOBILE, LKA-115	Hatten	BM-3	Hoseman, Repair 3	24	6	1	179	Lrg
USS MOBILE, LKA-115	Hackney, MG	SA	Exterior Investigator, Repair 2	20	6	1	180	-
USS MOBILE, LKA-115	Gutierrez, JG	E-2, SA	Scrubbed Contaminated Areas	21	5	6	136	*Med
USS MOBILE, LKA-115	Asereto, A	E-2, SA	Scrubbing Contaminated Areas, Repair 2	25	5	5	145	Sm
USS MOBILE, LKA-115	Abernathy	E-4, BM-3	Scrubbing Contaminated Areas, Repair 2	22	6	1	187	*Med
USS CROMMELIN,FFG-37	Kennedy, TB	-	Scrubbing Contaminated Areas, Repair 2	20	6	1	219	*Med
USS CROMMELIN,FFG-37	Hovde	SK/SA	Scrubbing Contaminated Areas, Repair 2	19	6	2	-	*Med
USS CROMMELIN,FFG-37	Mijares, LH	E-2	Scrubbing Contaminated Areas, Repair 2	22	5	7	130	*Med
USS CROMMELIN,FFG-37	Gonzaga, EM	MS1	Scrubbing Contaminated Areas, Repair 2	33	5	7	155	Med

RESULTS (Continued)

TABLE XIV. Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Personnel Data (Continued)

Location/ Ship	Name	Rank/ Rate	Station/ Duties	Age (yrs)	Height ft.	in.	Weight (lbs)	Size Worn
USS CROM-MELIN,FFG-37	Banzuela, JH	SA	Scrubbing Contaminated Areas, Repair 2	27	5	6	136	-
USS CROM-MELIN,FFG-37	Lang	SM3	Scrubbing Contaminated Areas, Repair 2	36	5	8	145	-
USS CROM-MELIN,FFG-37	Marshall, JC	BM2	Scrubbing Contaminated Areas, Repair 2	23	6	2	210	-
USS CROM-MELIN,FFG-37	McVay, D	BM2/SW	Scrubbing Contaminated Areas, Repair 2	23	6	0	165	-
NAEC	-	-	Aircraft Handling, and Launching	-	6	2	210	-
NAEC	-	-	Aircraft Handling, and Launching	-	5	6	145	-
NAEC	-	-	Aircraft Handling, and Launching	-	5	10	170	-
NAEC	-	-	Aircraft Handling, and Launching	-	6	1	170	*Med

* Wrong size suit issued

RESULTS (Continued)

TABLE XV. Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Data for Ships and Port Based Unit

		Location/Ship					
		Amphib CB-1		USS MOBILE LKA 115		USS CROMMELIN FFG-37	
Characteristic		# of Resp.	Avg. (%)	# of Resp.	Avg. (%)	# of Resp.	Avg. (%)
# Days Worn		3	0 days	2	0 days	6	0 days
# Hours		3	< 1 hrs	6	1.5 hrs	6	1.6 hrs
Donning							
Easy	Yes	2	50	7	78	7	88
Difficult	Yes	2	50	2	22	1	12
Adjusting Fit							
Easy	Yes	3	75	9	100	7	88
Difficult	Yes	1	25	0	0	1	12
Compatibility Problems:							
Gloves	Yes	0	0	1	11	0	0
	No	4	100	8	89	2	100
Footwear Covers	Yes	0	0	0	0	0	0
	No	4	100	9	100	1	100
MCU-2/P Mask	Yes	0	0	0	0	1	13
	No	4	100	9	100	7	87
Component Problem	Yes	2	50	4	44	4	47
	No	2	50	5	56	3	43
Closure Usage							
Easy	Yes	4	100	6	67	7	88
Difficult	Yes	0	0	3	33	1	12

RESULTS (Continued)

TABLE XV. Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Data for Ships and Port Based Unit (Continued)

		Location/Ship					
		Amphib CB-1		USS MOBILE LKA 115		USS CROMMELIN FFG-37	
Characteristic		# of Resp.	Avg. (%)	# of Resp.	Avg. (%)	# of Resp.	Avg. (%)
Experienced Skin Problems	Yes	0	0	1	11	1	12
	No	4	100	8	89	7	88
Experienced Discomfort,	Yes	0	0	1	11	5	62
	No	4	100	8	89	3	38
Temperature Conditions							
Fit of ICPO:							
Avg. to Good	Yes	4	100	9	100	7	88
Marginal to Poor	Yes	0	0	0	0	1	12
Adequacy of Pockets							
Location	Yes	4	100	8	89	7	100
	No	0	0	1	11	0	0
Accessi-bility	Yes	4	100	7	88	7	100
	No	0	0	1	12	0	0
Size	Yes	4	100	7	88	7	100
	No	0	0	1	12	0	0
Freedom of Movement:							
Good to Excellent	Yes	4	100	9	100	7	88

RESULTS (Continued)

TABLE XV. **Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Data for Ships and Port Based Unit (Continued)**

		Location/Ship					
		Amphib CB-1		USS MOBILE LKA 115		USS CROMMELIN FFG-37	
Characteristic		# of Resp.	Avg. (%)	# of Resp.	Avg. (%)	# of Resp.	Avg. (%)
Freedom of Movement: Marginal to Poor	Yes	0	0	0	0	1	12
Able to Perform Duties	Yes	4	100	9	100	7	88
	No	0	0	0	0	1	12
Safety Related Problems	Yes	0	0	0	0	1	12
	No	4	100	9	100	7	88
Any Damage to ICPO	Yes	1	25	0	0	0	0
	No	3	75	9	100	8	100
Overall Preference for ICPO Versus CPO	Yes	1	100	8	100	3	75
	No	0	0	0	0	1	25

The summary data provided in Table XVI indicate, that of 51 responses regarding the ICPO and CD IPE worn, 43 were negative and 8 were positive. Most of the negative responses (28), were associated with the hood (16), donning (6), and hot (6). The positive responses (8), were related to fit (3), comfort (2), zipper (1), elastic wristlets (1), and mask (1).

Of 25 responses concerning the best feature of the ICPO, most (15), were related to donning (4), easy to wear (3), zipper (3), protection (3), and fasteners (2). Of the 18 responses concerning the worst feature of the ICPO, most (10), were related to the hood (3), none (3), hot (2), and charcoal marks (2).

RESULTS (Continued)

Of the 17 responses regarding improvements needed, most (6), were related to nothing (4), and preventing charcoal from staining the underclothing and skin (2). There were three (3) responses showing preference for the ICPO compared to the current CPO: the ICPOs were more durable, insufficient time to comment on durability, and never wore the CPO.

TABLE XVI. Summary of Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Comments for Shipboard and Port Based Unit

Item	Comments	
	Positive	Negative
Hood	-	16
Trousers	-	2
Fasteners	-	1
Zipper	1	1
Scrim	-	2
Elastic Wristlets	1	1
Pockets	-	2
Fit	3	1
Donning	-	6
Mobility	-	1
Durability	-	1
Air Tightness	-	1
Hot	-	6
Comfort	2	-
Mask	1	-
Gloves	-	1
Training	-	1
TOTAL	8	43

RESULTS (Continued)

TABLE XVI. **Summary of Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Comments for Shipboard and Port Based Unit (Continued)**

Best Feature	# of Resp.	Worst Feature	# of Resp.	Improvements Needed	# of Resp.
Fasteners	2	Hood	3	Nothing	4
Trousers	1	Trousers	1	Hood	1
Zipper	3	Zipper	1	Size	1
Pockets	1	Size	1	Zipper in Trouser Legs	1
Fit	1	Air Tightness	1	Attach Gloves to Sleeve	1
Durability	1	Hot	2	Remove Hood Zipper	1
Easy Donning	4	Bulk	1	Pen Pocket on Left	1
Easier to Wear	3	Charcoal Marks	2	Sleeve	
Mobility	1	Mask	1	Waterproof	1
Compatibility	1	None	3	Prevent Charcoal and	
Protection	3	Footwear Covers	1	Scrim from Leaving	
Whole Thing	1	Protection	1	Marks on Clothing	2
Cooler than CPO	1			and Skin	
Mask	1			Longer Fasteners	1
Gloves	1			Thinner Material	1
				Make Cooler	1
				Build in Ice Packs	1
TOTAL	25	**TOTAL**	18	**TOTAL**	17

Preference, ICPO Versus CPO	
More Durable	1
Insufficient Time to Comment on Durability	1
Never Wore the CPO	1
TOTAL	3

RESULTS (Continued)

Simulated Flight Deck Tests

Four (4) volunteers wearing the ICPOs and CD and FD IPE conducted simulated aircraft handling and launching drills at NAEC (see Table XIV for personnel data). These volunteers ranged in height from 5 feet 6 inches to 6 feet 2 inches, and weighed 145-210 lbs. Responses to the questionnaire provided are shown in Table XVII. A summary of the anecdotal comments from the participants are provided in Table XVIII. A complete text of these comments is provided in Appendix C3. Tests were monitored by NAEC and NCTRF personnel.

Based on Table XVII data, participant responses indicated that 75% or more thought donning and adjusting fit was difficult; that there were no compatibility problems with gloves, footwear covers, MCU-2/P mask, cranial helmet, life vest, and communications; closure usage was easy; that there were no skin problems; the fit of the ICPO was average to good; the pockets were adequate regarding location, accessibility, and size; freedom of movement was good to excellent; that they were able to perform their assigned duties; and there were no safety-related problems. Sixty seven percent (67%) of the participants indicated that there were no component problems, comfort was fair to excellent, and preference for the ICPO compared to the CPO.

The summary data provided in Table XVIII, indicate that of ten (10) responses regarding the ICPO and CD and FD IPE worn, eight (8) were negative and two (2) were positive. The negative responses (8), were associated with the hood (2), mask (1), donning (3), and ability to perform duties (2). The positive responses (2), were related to fit (1), and comfort (1). The best features indicated for the ICPO (3) were mobility (1), trousers (1), and everything (1). The worst features were the hood (1) and heat (1). Improvements recommended were the hood (2) and none (1). There were no comments regarding preference for the ICPO compared to the CPO.

RESULTS (Continued)

TABLE XVII. **Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Data for Simulated Flight Deck Operations Conducted at NAEC**

Characteristic			Number of Responses	Average (%)
Donning				
	Easy	Yes	0	0
	Difficult	Yes	4	100
Adjusting Fit				
	Easy	Yes	1	25
	Difficult	Yes	3	75
Compatibility Problems:				
Gloves		Yes	0	0
		No	4	100
Footwear Covers		Yes	0	0
		No	4	100
MCU-2/P Mask		Yes	0	0
		No	4	100
Cranial Helmet		Yes	1	25
		No	3	75
Life Vest		Yes	1	25
		No	3	75
Communications		Yes	1	25
		No	3	75
Component Problem		Yes	1	33
		No	2	67
Closure Usage				
	Easy	Yes	2	100
	Difficult	Yes	0	0

RESULTS (Continued)

TABLE XVII. Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Data for Simulated Flight Deck Operations Conducted at NAEC (Continued)

Characteristic		Number of Responses	Average (%)
Experience Skin Problems	Yes	0	0
	No	3	100
Fit of ICPO:			
Average to Good	Yes	3	100
Marginal to Poor	Yes	0	0
Comfort of ICPO:			
Fair to Excellent	Yes	2	67
Marginal	Yes	1	33
Adequacy of Pockets:			
Location	Yes	3	100
	No	0	0
Accessibility	Yes	3	100
	No	0	0
Size	Yes	3	100
	No	0	0
Freedom of Movement:			
Good to Excellent	Yes	3	100
Marginal to Poor	Yes	0	0
Able to Perform Duties	Yes	3	100
	No	0	0
Safety Related Problems	Yes	0	0
	No	4	100
Overall Preference for the ICPO Versus CPO	Yes	2	67
	No	1	33

RESULTS (Continued)

TABLE XVIII. Summary of Interim Chemical Protective Overgarment Operational Demonstration Questionnaire Comment for Simulated Flight Deck Operations Conducted at NAEC

Item	Comments Positive	Comments Negative
Hood	-	2
Mask	-	1
Donning	-	3
Fit	1	-
Comfort	1	-
Ability to Perform Duties	1	2
TOTAL	2	8

Best Feature	# of Resp.	Worst Feature	# of Resp.	Improvements Needed	# of Resp.
Mobility	1	Hood	1	None	1
Trousers	1	Heat	1	Hood	2
Everything	1				
TOTAL	3	TOTAL	2	TOTAL	3
Preference, ICPO Versus CPO					No Comments

Land Based Site

CDTF, Fort McClellan was the land based site involved in the OPDEMO. Their effort simulated chemical defense conditions associated with ground support troops. After evaluating several ICPOs under these conditions, a summary of their findings of design modifications needed was as follows:

1. Hook and loop fasteners should be placed around the entire wrist area of the sleeve. Current fastener is inadequate.

2. Either the trousers pockets need to be lowered or the jacket length shortened, because the jacket covers the trousers pockets.

3. Knee patches could be smaller.

RESULTS (Continued)

4. The jacket pockets should be raised to become breast pockets. When the canteen is worn with the web belt, the web belt covers the jacket pockets, and they are inaccessible.

5. All the pockets should be bellows type to make it easier to get your hands in and out of them, especially with the gloves on.

6. A barrel lock should be put on the jacket bottom drawstring to make tightening the jacket easier.

7. The ICPO should be made out of a lighter colored material, like beige so that the heat can be reflected more by the material. Dark materials are not acceptable. White should be avoided, because on a sunny day it will reflect too much light and make it difficult for personnel to see.

DISCUSSION OF RESULTS

Outer Shell Materials

The significance of the physical characteristics of the outer shell material used in a *chemical protective overgarment, for* application in a naval environment, relate to short term durability (14 days wear), comfort (lightweight, low stiffness, and high air permeability), environmental protection (water repellency and hydrostatic resistance), flame and heat protection (vertical flammability resistance, and radiant and convective/radiant heat protection), and chemical agent protection (prevention of liquid chemical droplets from penetrating directly to the anti-gas cloth).

Based on these criteria the modacrylic/nylon, cotton, and polyester/cotton outer shell materials provided sufficient durability (adequate break and tear strength) for this application (Table II). The modacrylic/nylon material would potentially provide the best comfort, being lighter and having a higher air permeability than the cotton and polyester/cotton materials. Regarding environmental protection, the cotton and polyester/cotton materials would provide better water spray resistance, and the cotton and modacrylic/nylon materials would provide the best hydrostatic resistance (Table II). For flame resistance and heat protection, the cotton and polyester/cotton materials provided equivalent protection in the vertical flammability, radiant, and convective/radiant heat exposures (Tables III, IV, and V). The modacrylic/nylon was not evaluated in the vertical flammability and heat protection tests, because its resistance to flames and high levels of heat energy is known to be marginal (melts), and this poor feature was why a new outer shell material was considered for the ICPO.

DISCUSSION OF RESULTS (Continued)

The ability of an outer shell material to prevent penetration of liquid droplets to the anti-gas cloth liner, can be judged partially by its water spray and hydrostatic resistance. As indicated previously the cotton and polyester/cotton materials had the best water spray resistance, and the cotton and modacrylic/nylon materials had the best hydrostatic resistance (Table II).

Considering the performance of the cotton and polyester/cotton material candidates with respect to the characteristics indicated, the modacrylic/nylon material not being suitable because of its poor flame and heat resistance, the cotton material performed better than the polyester/cotton material. The cotton material was lighter in weight, had an equivalent breaking strength, higher tear strength, lower stiffness, better abrasion resistance, equivalent water spray resistance, and higher hydrostatic resistance (Table II); and equal flame resistance, and radiant and convective/radiant heat protection (Table III, IV, and V). The only property where the polyester/cotton material performed better than the cotton, was its higher air permeability (Table II).

Anti-Gas Cloth Liner

The function of the anti-gas cloth is to adsorbed chemical agent vapor, whether the vapor is derived from liquid droplets lying on the surface of the outer shell material, or results form a direct vapor challenge. The loss of any charcoal as a result of abrasion, reduces the vapor adsorption capacity of the anti-gas cloth. Abrasion tests of the back surface of the F and G Specification cloths, with and without a nylon scrim, against a FRT chambray shirting material, that would normally be worn as underclothing next to the anti-gas cloth, showed that the G Specification cloth with the nylon scrim had less charcoal loss than the F and G Specification cloths, and the G Specification cloth had less charcoal loss than the F Specification cloth.

Material Assemblies

Heat Protection Tests

The heat resistant nature of the outer shell material is important to the overall heat protection provided by a material assembly, particularly in this application, since the charcoal in the anti-gas cloth can have a sustained after glow, if its temperature is raised to a high enough level. The cotton outer shell material is not normally subject to breakthrough from heat exposure, since it does not melt or shrink. A polyester/cotton outer shell material does not breakthrough either, when exposed to heat, if there is sufficient cotton in the blend to absorbed the melting polyester. However, secondary heat transfer to the anti-gas cloth can occur if some of the polyester melt material flows into it, raising the temperature of the anti-gas cloth above what would occur with a non-meltable outer shell material. Radiant heat protection tests of the cotton and polyester/cotton candidate outer shell materials with the G Specification anti-gas cloth liner, showed the peak heat flux transmitted through the assemblies to be slightly higher with the polyester/cotton - anti-gas cloth assembly compared to the cotton - anti-gas cloth assembly. Estimated time to burn injury was 35 seconds for the cotton assembly and 31 seconds for the polyester/cotton assembly (Table IV). The heat energy transferred through the assemblies in the convective/radiant heat tests was also higher with the polyester/cotton - anti-gas cloth assembly compared to the cotton - anti-gas cloth assembly. Estimated time to burn injury was ten (10) seconds for the cotton assembly and nine (9) seconds for the polyester/cotton assembly (Table V). In the convective/radiant heat tests there was sufficient heat energy transferred through the polyester/cotton - anti-gas cloth assembly to cause after glow of the charcoal in the anti-gas cloth, which could have potentially caused a lower time to burn injury than the nine (9) seconds estimated, if the test was continued until the glow ceased.

Chemical Agent Tests

New Materials

Liquid Challenge/Vapor Penetration Tests

In the HD liquid challenge/vapor penetration (L/V) tests, the minimum breakthrough time was 16 hours with the F Specification liner with all the three (3) outer shell materials, the current modacrylic/nylon, and the candidate cotton and polyester/cotton outer shell materials; 16, 24, and 32 hours with the G Specification liner for the cotton, modacrylic/nylon, and polyester/cotton outer shell materials, respectively; and 32 hours for the G Specification liner with the nylon scrim for all three (3) outer shell materials (Table VIII). The G Specification liner, with and without the nylon scrim, had higher breakthrough times than the F Specification liner with all the outer shell materials, except for the cotton and G Specification liner condition, where the breakthrough time (16 hours) was equal to the performance of the F Specification liner with all the outer shell materials. The G Specification liner with the nylon scrim, had a higher breakthrough time (32 hours) than the G Specification liner without the nylon scrim with all the outer shell materials, except for the polyester/cotton and the G Specification liner assembly, which also had a breakthrough time of 32 hours. Why there was a difference in the breakthrough times between the G Specification liner with the nylon scrim, and the G Specification liner without the nylon scrim is not clear, because the nylon scrim should not enhance chemical protection directly. Other chemical agent tests previously conducted at the U.S. Army Chemical Research, Development, and Engineering Center (CRDEC), showed that the FRT cotton chambray shirting and cotton t-shirt backing materials used in all the chemical tests, only accounted for 0.9 to 1.1 hours of increased breakthrough time.[12] A possible reason may be differences in the relative age of the liner materials based on their date of manufacture. Information on the dates of manufacture and lot numbers was not available for the liner materials. It is well known that the chemical agent vapor adsorption capacity of the liners is negatively affected by time in storage. Activated charcoal is a universal adsorbent, and tends to adsorb any chemical vapors that may out-gas from the chemical finishes and adhesives used in manufacturing of the liner, the packaging materials employed, or which may exist in the general storage environment. The temperature of the storage environment also influences the rate of out-gassing from these materials, with higher rates occurring as temperatures increase.

Based on the chemical data available, the minimum breakthrough times shown in Table VIII indicate in general, that the three (3) outer shell materials performed equally in preventing liquid chemical agent droplets from penetrating to the liner, and the G Specification liner, with and without the nylon scrim, had greater chemical vapor adsorption capacity than the F Specification liner. The breakthrough times were identical with the F Specification liner (16 hours) and the G Specification liner with the nylon scrim (32 hours) with all the outer shells. With the G Specification liner without the nylon scrim, the breakthrough times varied, 16 hours with the cotton, which was identical to the result with the F Specification liner, 24 hours with the modacrylic/nylon, which was intermediate to the results for the F Specification liner and G Specification liner with the nylon scrim, and 32 hours with the polyester/cotton, which was identical to the result with the G Specification liner with the nylon scrim.

When the multiple chemical agent dosages used in these tests are considered, simulating a new chemical attack every eight (8) hours (the addition of two (2), one (1) mg drops at the start of each test and every eight (8) hours thereafter, until the failure point was reached), the differences between the chemical agent vapor adsorption capacity of the G Specification liner with the nylon scrim and the F Specification liner were greater than the factor of two (2) indicated by the breakthrough times (32 versus 16 hours). The G Specification liner with the nylon scrim was subjected to eight (8) mg of liquid agent between 0 and 24 hours, prior to breakthrough at 32 hours, while the F Specification liner was subjected to only four (4) mg. of liquid agent between 0 and 8 hours, prior to breakthrough at 16 hours.

Vapor Contamination/Vapor Penetration Tests

In the HD vapor contamination/vapor penetration (V/V) tests, the presence of an outer shell material is relatively insignificant (permeable), the liner materials alone adsorb the agent vapor applied (20 $\pm$ 2 micrograms/liter). The breakthrough times ranged from less than eight (8) to 16 hours for the F Specification liner, was 16 hours for the G Specification liner, and ranged from eight (8) to 16 hours for the G Specification liner with the nylon scrim (Table IX). The variation in breakthrough time, particularly for the F Specification liner, may be related to the influences on vapor adsorption capacity discussed under the L/V tests, that the age of the liner material affects chemical agent vapor capacity, because of the out-gassing of chemicals used in the construction of the liner, as well as the packaging materials, including temperature effects. Since the G Specification liners superseded the F Specification liners, it is highly probable that the F Specification liners were older than the G Specification liners, based on their date of manufacture. The breakthrough time for the G Specification liner, with and without the nylon scrim, was identical (16 hours) except for one test, where the breakthrough time was eight (8) hours for the G Specification liner with the nylon scrim and the modacrylic/nylon outer shell.

In general, the G Specification liners, with and without the nylon scrim, had a breakthrough time that was twice as long (16 hours in five (5) of six (6) tests) compared to the F Specification liner (eight (8) hours or less in two (2) of three (3) tests). If the normal assembly arrangement is considered, the F Specification liner and the modacrylic/nylon outer shell, and the G Specification liner, with and without the nylon scrim, and the cotton and polyester/cotton outer shells, the breakthrough was 16 hours for all assemblies.

Worn Overgarment Materials

In these tests only five (5) OGs were tested, and the number of hours the OGs were worn is unknown. In the L/V and V/V tests, a material assembly from each smock and trousers was evaluated, from one (1) current CPO with the F Specification liner and modacrylic/nylon outer shell, from two (2) ICPOs with the G Specification liner, and cotton and polyester/cotton outer shells, and from two (2) additional ICPOs with the G Specification liner with nylon scrim, and the cotton and polyester/cotton outer shells.

Liquid Challenge/Vapor Penetration Tests

In the L/V tests, breakthrough times for the current CPO material assembly, were 32 hours for the smock and 24 hours for the trousers. For the ICPOs with the G Specification liner, with and without the nylon scrim, and with the cotton outer shell, breakthrough times were 16 and 24 hours, respectively for the smocks, and 24 and 32 hours, respectively for the trousers. For the ICPOs with the G Specification liner, with and without the nylon scrim, and with the polyester/cotton outer shell, breakthrough times were 32 and 24 hours, respectively for the smock and the trousers of each ICPO (Table X). The smock of the G Specification liner with the nylon scrim and cotton outer shell had the lowest breakthrough time (16 hours). For all other OG components, breakthrough times were 24 and 32 hours.

The breakthrough times, for the "worn" F Specification and modacrylic/nylon assemblies were greater than occurred in the "new" material tests for this type of material assembly (Table VIII), 32 and 24 hours for the "worn" materials compared to 16 hours for the "new" material tests. Again the age of the "worn" and "new" F Specification liners was unknown, and possibly accounts for the reversal in the breakthrough times, since the "worn" OGs were expected to have lower agent adsorption capacity than "new" OGs.

This condition also occurred between the "worn" ICPO with the G Specification liner and the cotton outer shell, and a similar "new" material assembly, where the breakthrough times were 24 and 32 hours for the smock and trousers, respectively for the "worn" ICPO and 16 hours for the new materials assembly. Only for the Number 4 ICPO with the G Specification liner, and all ICPOs with the G Specification liner and nylon scrim, did the equivalent "new" material assemblies have higher or equal breakthrough times (32 hours) compared to the "worn" ICPOs, where the breakthrough times ranged from 16 to 32 hours.

Vapor Contamination/Vapor Penetration Tests

In the V/V tests (Table XI), the breakthrough time for the current CPO material assemblies was eight (8) hours for the smock and trousers. For the G Specification liner, with and without the nylon scrim, and the cotton outer shell, breakthrough time was eight (8) hours for the smocks, and eight (8) and 24 hours, respectively for the trousers. For the G Specification liner, with and without the nylon scrim, and the polyester/cotton outer shell, breakthrough times were 24 and 16 hours, respectively for the smocks, and eight (8) and 16 hours, respectively for the trousers. Compared to the V/V tests for "new" materials (Table IX), the breakthrough time for the "worn" F Specification liner was lower (eight (8) hours) versus the new liner (16 hours). For the "worn" G Specification liner with the cotton outer shell, the breakthrough time for the smock (eight (8) hours) and the trousers (24 hours) was lower and higher, respectively versus 16 hours for the new G Specification liner with the cotton outer shell, and equivalent for the "worn" and "new" G Specification liners with the polyester/cotton outer shell (16 hours). For the "worn" G Specification liner with the nylon scrim and the cotton outer shell, the breakthrough time for the smock and trousers (eight (8) hours), was lower versus the "new" G Specification liner with the nylon scrim and the cotton outer shell (16 hours), and for the "worn" G Specification liner with the polyester/cotton outer shell, the breakthrough time was higher for the smock (24 hours) and lower for the trouser (eight (8) hours), respectively versus the "new" G Specification liner with the polyester/cotton outer shell (16 hours). Not knowing the history of these materials, the up and down variations between the "new" and "worn" liners cannot be readily explained. "Worn materials should have less chemical agent adsorption capacity than "new" materials, but as seen in these results, there were several instances where the "worn" materials had higher chemical agent adsorption capacity than the "new" materials.

Overgarments

Flame Envelopment Tests, (Table VI)

The ICPO with the polyester/cotton outer shell and the G Specification liner, with and without the nylon scrim, performed best in these tests. There was no burn injury measured, and the maximum after flame was only four (4) seconds, with heat flux levels ranging from 2.1 to 3.4 g cal/cm^2/sec. The cotton ICPO with the G Specification liner, with and without the nylon scrim, was considered second best. In one (1) of three (3) tests with a heat flux level of 3.1 g cal/cm^2/sec, a body area burn injury of 3.5% was incurred with a significant after flame time of 32 seconds, before the flame was quenched with a fire extinguisher. In the other two (2) tests, with heat fluxes of 1.7 and 2.6 g cal/cm^2/sec, no burn injury occurred, and the after flame time was only two (2) seconds, in the test having a heat flux of 2.6 g cal/cm^2/sec. The current CPO was considered worse than the ICPOs in providing flame envelopment protection, even though no burn injury occurred in any of the three (3) tests conducted, because in two (2) tests with a heat flux of 2.6 g cal/cm^2/sec the after flame time was 30 seconds, before the flames were quenched with a fire extinguisher. In these tests, the modacrylic/nylon outer shell material had completely melted exposing the charcoal liner. In tests of the cotton and polyester/cotton ICPOs, where the heat flux level was equivalent, only a two (2) second after flame time occurred with the cotton ICPO, and no after flame time occurred with the polyester/cotton ICPO.

Biophysical and Physiological Evaluations

For the MOPP Level 4 condition conducted in the biophysical and physiological evaluations, with the cotton and polyester/cotton ICPOs, and the current CPO, there were no differences between the OGs. In the biophysical evaluation, the thermal insulation values were between 2.1 and 2.2 CLO, the water vapor permeability values (Im) between 0.36 and 0.37, and the Im/CLO values between 0.16 and 0.18 for the OGs (Table VII). In the physiological evaluation for the hot-dry (49°C, 20% RH, and 2.2 m/s wind) and hot-humid (35°C, 75% RH, and 4.5 m/s wind) environments, the differences in tolerance times between the OGs were statistically insignificant ($p > 0.05$). For the hot-dry environment, average tolerance time was 77 minutes for the current CPO, 70 minutes for the cotton ICPO, and 71 minutes for the polyester/cotton ICPO. In the hot-humid environment, average tolerance time was 101 minutes for the current CPO, 87 minutes for the cotton ICPO, and 101 minutes for the polyester/cotton ICPO.

For the MOPP Level 3 condition in the biophysical evaluation, the thermal insulation values were between 1.9 and 2.0 CLO, the water vapor permeability values (Im) between 0.51 and 0.54, and the Im/CLO values between .26 and .28 for the OGs (Table VII). The change in the Im/CLO values between MOPP Levels 3 and 4 in the biophysical evaluation, represents a 56-63% increase in the amount of body heat that can be dissipated at MOPP Level 3 compared to MOPP Level 4 with all OGs. The ability to maintain military personnel in MOPP Level 3 or lower for the maximum time possible, prior to a chemical attack, would be very effective in reducing their overall heat strain.

Compatibility Tests

Physical Compatibility

In the physical compatibility tests conducted at NAEC with the modified CPOs, most volunteers (75% or more) provided positive responses to the information requested in the questionnaire (Table XII). Responses were associated with donning, fit adjustment, compatibility with chemical and flight deck IPE, closure usage, skin irritation, comfort, pocket location, size, and accessibility, freedom of movement, and modified CPO damage. Sixty percent (60%) or more provided positive responses to questions concerned with fit, ability to perform duties, safety problems, and preference for the modified CPO compared to the current CPO. Fourty five percent (45%) had component problems and 78% experienced temperature discomfort. Summary data from the questionnaire comments (Table XIII) indicate that 77 were negative and five (5) positive. Most of the negative comments were associated with the NAEC modified hood (23) and the chemical IPE (35). The enlargement of the hood to accommodate the cranial helmet worn by flight deck personnel, created difficulties in obtaining a good hood/mask interface.

For comments concerning the best feature of the modified CPO, most related to the fasteners, fit, weight, smock, and trousers. Another best feature was the MCU-2/P mask drinking tube. Comments regarding the worst feature of the modified CPO were related to the hood, ability to perform duties, and heat discomfort. For the chemical IPE, several personnel disliked the footwear covers and the MCU-2/P mask. Comments related to improvements needed, were associated with the hood and the chemical IPE, MCU-2/P mask and the footwear covers (Table XIII). Disregarding the existing chemical IPE, the hood/mask interf[illegible] associated with the enlarged hood of the modified CPO, which is needed to acco[illegible]te the flight deck cranial helmet, caused the most serious compatibility problem, and the resulting potential loss in chemical protection.

Physical and Simulated Chemical Agent Compatibility

The cotton and polyester/cotton ICPOs and the current CPO were evaluated in these tests. The ICPOs were evaluated with the MCU-2/P mask, with and without the cranial helmet, and the MK V mask without the cranial helmet. The current CPO was tested with the MCU-2/P and MK-V masks. The ICPOs were found to be incompatible with the MCU-2/P and MK V masks, and the cranial helmet. When the ICPOs were tested with the MCU-2/P mask without the cranial helmet, there were gaps at the hood/mask interface. When tested with the MK V mask without the cranial helmet, the hood slipped down over the mask lens because the hood drawstrings had nothing to secure to, causing a poor seal at the hood/mask interface. The excessive amount of hood material crated when the cranial helmet was not worn, adds to the difficulty of obtaining a good seal around the masks.

When the ICPOs were tested with the MCU-2/P mask, and with personnel wearing the cranial helmet, there were also compatibility problems, because the hood was not large enough to accommodate all cranial helmet sizes. This resulted in large open gaps near each ear, and a poor fit in the forehead area.

When the ICPOs with the MCU-2/P mask were sprayed with chemical agent simulant, with and without the cranial helmet, it was determined during CCA processing, that there was no simulant penetration of the ICPOs.

There were also compatibility problems at the mask/hood interface area, when the current CPO was evaluated with the MCU-2/P and MK V masks. After securing the hood to the masks, arm, and neck stretching caused gaps in the lower chin area of the hood with both masks.

Summary

In both the physical and physical and simulated chemical agent compatibility tests, problems with the enlarged hood were noted. The incompatibility of the enlarged hood design with the MCU-2/P and MK V masks, with and without the cranial helmet being worn, requires a redesign of the hood before any other activity with the ICPOs is considered.

DISCUSSION OF RESULTS (Continued)

Operational Demonstration

Ships

USS JARRETT, FFG-33; USS DULUTH, LPD-6; USS CONNOLLY, DD979

From chemical defense drills conducted by damage control personnel aboard the JARRETT, DULUTH, and CONNOLLY, wearing the ICPOs and CD IPE, there were comments from all ships regarding an inadequate hood/mask interface with either the MCU-2/P or MK V masks, because of difficulties in securing the hood to the mask and the glove/sleeve interface, because of the positioning of the hook and loop tapes. The CONNOLLY felt that the positioning of the hook and loop tapes made it difficult to get a good seal at the trouser cuff/footwear cover interface, and adjusting the fit of the hood. Other comments from the JARRETT and DULUTH were related to the heavier weight of the ICPOs compared to the current CPO, the inadequacy of the knee and elbow patches (too stiff), the dark colors of the ICPOs contributing to heat strain when functioning topside on a sunny day, and concern that the atropine and 2 M-chloride injectors may not penetrate the new materials. Other comments from the CONNOLLY were concerned with how easy the leg hook tabs tore off, the bleeding of the charcoal when it is wetted from sweating, and that a smock with a zipper would not provide an adequate seal.

As in the compatibility testing at NSWC, the hood/mask interface of the ICPOs with the MCU-2/P and MK V masks, was also recognized as being inadequate in these ship tests. Other comments from ship personnel suggest, that all hook and loop tape closures need to be repositioned to be effective, and strengthened to prevent tearing of the tapes. When the other criticisms are considered (weight, knee and elbow patches, color, etc.) there appeared to be little about the ICPOs that ship personnel liked.

Ships and Port Side Unit

The USS MOBILE, LKA-115, and the USS CROMMELIN, FFG-37, were involved in conducting shipboard chemical defense drills, and Amphib CB-1, Naval Air Station, Coronado, California was involved in port side chemical defense drills, wearing the candidate ICPOs and CD IPE. Personnel data from these units and responses to the questionnaire are provided in Tables XIV and XV. A summary of anecdotal comments from the participants are shown in Table XVI. A complete text of their comments are provided in Appendix C2.

Personnel data (Table XIV) indicated that at least six (6) of the 21 participants were issued the wrong size OG, and the duties conducted during the evaluation ranged from driving a boat to operating a forklift for port side personnel, and conducting agent detection and decontamination exercises for shipboard personnel.

When responses to questionnaire criteria were combined for the ships and port side unit, 75% or more, were positive for characteristics such as donning, adjusting fit, compatibility with CD IPE, closure usage, skin problems, fit, pockets, freedom of movement, ability to perform duties, safety related problems, damage to the ICPO, and overall preference for the ICPO versus the current CPO. Fifty percent (50%) had component problems and 29% experienced temperature discomfort. The summary comments (Table XVI), provided a contrasting input. Of 51 comments, 43 were negative, with most (16) being associated with the enlarged hood. Of the eight (8) positive comments, most (3) were associated with fit. There were 25 comments regarding the best feature of the ICPOs, and 18 comments regarding the worst feature of the ICPOs. Of those comments associated with the best feature, easy donning was mentioned four (4) times; and the zipper, easy wear, and protection were each mentioned three (3) times. Of those comments associated with the worst feature, the enlarged hood and none were each mentioned three (3) times, and hot and charcoal marks were each mentioned two (2) times. Of 17 comments related to improvements needed; nothing was mentioned four (4) times, and prevention of charcoal and scrim marks was mentioned two (2) times.

Similar to previous inputs, physical, and simulated chemical agent compatibility tests, and results from chemical defense drills aboard the JARRETT, DULUTH, and CONNOLLY, the enlarged hood was the major problem source, affecting primarily the ability to obtain a good seal at the hood/mask interface.

Simulated Flight Deck Tests

Four (4) people wearing the ICPOs and CD and FD IPE were used to conduct the simulated aircraft handling and launching drills at NAEC. Information on the participants is provided in Table XIV, responses to questionnaire are shown in Table XVII, and summary data of anecdotal comments are provided in Table XVIII. A complete text of these comments is provided in Appendix C3.

Of the positive responses received regarding the questionnaire criteria (Table XVII), at least three (3) of four (4) were related to compatibility, closure usage, skin problems, fit, pockets, freedom of movement, ability to perform duties, and safety related problems. For other positive responses, two (2) of three (3) indicated no component problems, comfort, and preference for the ICPO versus the current CPO. All four (4) participants found donning difficult, and three (3) of four (4) found adjusting fit difficult. Of the summary comments (Table XVIII), eight (8) of ten (10) were negative with three (3) related to donning, and two (2) each related to the hood

DISCUSSION OF RESULTS (Continued)

and the ability to perform duties. The two (2) positive comments were fit (1) and comfort (1). Comments on the best feature of the ICPO (3), indicated mobility, trousers, and everything. Comments on the worst feature of the ICPO (2), were related to the enlarged hood and heat. Of three (3) comments regarding improvements needed, two (2) were related to the enlarged hood, and one (1) was related to none. As with the ships and port side tests, the comments contrast with the questionnaire responses.

Land Based Unit

Comments received from CDTF, Fort McClellan, Alabama regarding the ICPOs, were related to the hook and loop tape at the wrist/glove interface, smaller knee patches, location of trousers and jacket pockets, style of pockets, the addition of a barrel lock for the jacket bottom drawstring, and using a lighter colored (beige) outer shell material to reflect some of the heat load imposed by the sun. This was essentially the only OPDEMO input that did not comment on the enlarged hood.

Summary

To have an effective ICPO, the enlarged hood must be redesigned to provide a good seal at the hood/mask interface, wearing the CD and FD IPE. This was apparent from all ships the port side unit, and the simulated flight deck site comments. Only the land based site made no comments on the hood.

Comments concerning the zipper were ambivalent, four (4) being positive and three (3) negative. Other comments were concerned with the weight of the ICPOs, the butyl knee and elbow patches, color of the ICPOs, donning problems, positioning of the fasteners and pockets, and heat strain. Comments related to the preference for the ICPO versus the CPO were invalid, citing durability, when the ICPOs were only worn for a few hours, not enough time wearing the ICPOs to determine durability, and never wore the CPO. There were also negative comments regarding the existing CD IPE, principally the footwear covers.

Other inputs from the physiological evaluation, and the physical and simulated chemical agent compatibility tests, respectively, indicated that heat strain would be a significant factor wearing the current CPO and the ICPOs when attempting to perform any active chemical defense duties in hot-dry and hot-humid environments, under the MOPP Level 4 condition, and there was poor compatibility between the MCU-2/P and MK V masks and enlarged hood, with and without the cranial helmet, respectively.

GOALS

Of the goals set forth for the ICPO, improved fire protection; reduced heat strain; improved chemical protection, wear, and storage life; and compatibility with IPE; the improved fire and chemical protection goals were achieved. The heat strain caused by the ICPO, in hot-dry and hot-humid environments, was equivalent to the current CPO; improvements in wear and storage life, as they relate to chemical protection, were not demonstrated; and the incompatibility of the ICPO hood with the MCU-2/P and MK V masks, with or without the flight deck cranial helmet, requires a complete redesigned of the hood.

The personnel involved in the OPDEMO did not encounter fire and chemical exposure, and as a result were not aware of these important improvements.

The final action resulting from the OPDEMO of the ICPO, replacing the F Specification anti-gas cloth with the G Specification anti-gas cloth, and maintaining the modacrylic/nylon outer shell and design of the current CPO, will enhance chemical protection, but fire protection will be marginalized, and the hood will be too small for flight deck personnel to wear the cranial helmet and aural sound protectors.

CONCLUSIONS

1. Of the two (2) ICPO candidate outer shell materials, FRT/WRT 100% cotton and FRT/WRT 50/50% polyester/cotton, the FRT/WRT 100% cotton material had the best physical properties. The cotton material was lighter in weight, had an equivalent breaking strength, higher tear strength, lower stiffness, better abrasion resistance, equal spray resistance, and higher hydrostatic resistance than the polyester/cotton material. The only physical property where the polyester/cotton material was better than the cotton material, was its higher air permeability.

2. The FRT/WRT 100% cotton and FRT/WRT 50/50% polyester/cotton ICPO candidate outer shell materials, had equivalent vertical flame resistance, and radiant and convective/radiant heat protection.

3. Abrasion tests of the anti-gas cloths evaluated for the ICPO, UK G Specification cloth, with and without a nylon scrim backing, versus the UK F Specification cloth used in the current CPO, showed that the UK G Specification cloth with the nylon scrim backing had the best abrasion resistance, less charcoal loss than the other two (2) cloths. The UK G Specification cloth was second best, with less charcoal loss than the UK F Specification cloth.

4. Heat protection tests of the ICPO candidate material assemblies; FRT/WRT 100% cotton outer shell and UK G Specification anti-gas cloth, and FRT/WRT 50/50% polyester/cotton outer shell and UK G Specification anti-gas cloth; indicate that the cotton anti-gas cloth assembly provided more heat protection in the radiant and convective/radiant heat tests. The estimated time to burn injury in the radiant heat tests was 35 seconds for the cotton assembly and 31 seconds for the polyester/cotton assembly. In the convective/radiant heat tests, the estimated time to burn injury was ten (10) seconds for the cotton assembly and nine (9) seconds for the polyester/cotton assembly.

5. In flame envelopment tests of the ICPOs and current CPO, cotton - G Specification anti-gas cloth ICPO, polyester/cotton-G Specification anti-gas cloth ICPO, and modacrylic/nylon-F Specification anti-gas cloth CPO; the polyester/cotton ICPO performed best, and the cotton ICPO was considered second best. In three (3) tests with the polyester/cotton ICPO, there was no burn injury, and an after flame time of only four (4) seconds occurred in one (1) of the three (3) tests. In one (1) of the three (3) tests with the cotton ICPO, there was a 3.5% body area burn injury, and an excessive after flame of 32 seconds before the flames were quenched with a fire extinguisher. In the other two (2) tests with the cotton ICPO, there was no burn injury, and an after flame of only two (2) seconds occurred in one (1) of these two (2) tests. In two (2) of three (3) tests with the modacrylic/nylon CPO, there was an

CONCLUSIONS (Continued)

excessive after flame of 30 seconds before the flames were quenched with a fire extinguisher. In these tests with the modacrylic/nylon CPO, the modacrylic/nylon outer shell melted, exposing the anti-gas cloth to the fire.

6. Biophysical tests of the candidate ICPOs and the current CPO at MOPP Levels 3 and 4, showed no difference between the ICPOs and the CPO. Their thermal insulation (CLO), water vapor permeability (Im), and Im/CLO values for each MOPP level condition was equivalent. The differences between the Im/CLO values, for MOPP Levels 3 and 4 for all overgarments, indicate an increase of 56-63% in body heat dissipation for MOPP Level 3 compared to MOPP Level 4.

7. A physiological evaluation of the candidate ICPOs and the current CPO at MOPP Level 4, in hot-dry and hot-humid environments with a moderate work load, found that there was no statistical difference in tolerance time between the overgarments ($p > 0.05$).

8. HD liquid chemical agent tests of new material assemblies used in the ICPOs and current CPO, showed the polyester/cotton G Specification anti-gas cloth ICPO assembly, with and without the nylon scrim, had a breakthrough time of 32 hours, the cotton G Specification anti-gas cloth ICPO assembly, with and without the nylon scrim, had breakthrough times of 32 and 16 hours, respectively, and the modacrylic/nylon F Specification anti-gas cloth CPO assembly, had a breakthrough time of 16 hours. In five (5) of six (6) tests employing the G Specification anti-gas cloth, with and without the nylon scrim, breakthrough times were 50-100% longer (24-32 hours) compared to the F Specification anti-gas cloth (16 hours).

9. HD vapor chemical agent tests of new material assemblies used in the ICPOs and current CPO, indicate that the cotton and polyester/cotton-G Specification anti-gas cloth ICPO assemblies, with and without the nylon scrim, and the modacrylic/nylon F-Specification anti-gas cloth CPO assembly had an equivalent breakthrough time of 16 hours.

10. The results of HD liquid and vapor chemical agent tests of worn overgarment material assemblies were inconclusive, because of the variability in the test results, and lack of information on the history of the materials, and the amount of time the overgarments were worn.

11. Physical and simulated chemical agent compatibility tests of the ICPOs, showed poor compatibility between the MCU-2/P and MK V masks and the enlarged hood of the ICPO, with and without the cranial helmet worn by flight deck personnel. Spray tests

CONCLUSIONS (Continued)

of the ICPO, with the chemical defense (CD) and flight deck (FD) individual protective equipment (IPE), using a chemical agent stimulant, indicated no stimulant penetration of the ICPO.

12. Operational demonstration tests of the ICPOs aboard five (5) ships, one (1) port side unit, and two (2) land based sites, where simulated chemical defense drills were performed with CD and FD IPE, showed that the most significant deficiency of the ICPOs, was the compatibility of the enlarged hood with the MCU-2/P and MK V masks, with and without the cranial helmet.

13. Of the goals established for the ICPO, improved fire protection, reduced heat strain, improved chemical protection, and compatibility with IPE, the improved fire protection and chemical protection goals were achieved. Heat strain was equivalent to that experienced with the current CPO. The incompatibility of the enlarged hood of the ICPO with the chemical masks, with and without the use of the flight deck cranial helmet, requires a redesign of the hood, if any further development of the ICPO is to be considered.

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APPENDIX A

MISSION ORIENTED PROTECTIVE POSTURE LEVELS FOR ICPO

MILITARY ORIENTED PROTECTIVE POSTURE (MOPP) FOR ICPO

MOPP Level - 0 Condition III or DEFCON - 3 in effect - suspected threat

1. Protective equipment are inspected and in ready condition in normal storage spaces.

2. Fresh filters are placed in mask.

MOPP Level - 1 Condition III - possible threat

1. Protective equipment issued to shipboard personnel.

2. Mask fitted for immediate use.

3. ICPO worn with smock open and hood not covering head.

4. Footwear covers, gloves, and mask are carried or located at battle station.

5. Atropine Auto Injectors (5), Pralidoxime Chloride Auto Injectors (2), and Amyl Nitrate Capsules (8) are issued by medical personnel and carried by ships force in mask carrier.

MOPP Level - 2 Condition III or Relaxed Condition 1 - probable threat

1. ICPO with smock open and mask are worn (without hood up).

2. Footwear covers and gloves are carried or located at battle station.

MOPP Level - 3 Condition I, Warning Yellow - confirmed threat

1. ICPO with smock open, mask, and footwear covers worn.

2. Gloves are carried and hood is not worn.

3. Topside personnel to seek shelter within the ship.

MILITARY ORIENTED PROTECTIVE POSTURE (MOPP) FOR ICPO (Continued)

4. a. CPS equipped ships should start up vent fans and build up internal pressure.

   b. Non - CPS equipped ships should secure (shut down) ventilation systems and set Circle (W) William fittings, closing all water tight doors and hatches.

MOPP Level - 4 Condition I, Warning Red - attack imminent

1. All protective equipment to be worn (smock closed, hood up, and secured).

2. Take all evasive action IAW tactical requirements.

NOTE: The setting of each level may be recommended to the CO by the DCA or Senior Hull Technician on tactical mission, work rate demand, and heat stress probabilities/actuals experienced by the various Battle Station areas (i.e., engine room, CIC, etc.).

APPENDIX B

QUESTIONNAIRE FORM

QUESTIONNAIRE
FOR EVALUATION OF
INTERIM CHEMICAL PROTECTIVE OVERGARMENT (ICPO)

Date: ______________________

Location: ______________________

I. PERSONNEL DATA

Name & Rank/Rate: ______________________

Station (Duties): ______________________

Age: __________ Height: __________ Weight: __________

Size of ICPO issued: __________

Number of days worn: __________ Number of hours per day: __________

II. EVALUATION DATA

1. HOW EASY WAS IT TO DON THE ICPO? (check one)

____ Very easy
____ Easy
____ Somewhat difficult
____ Very difficult

Comments/Problems: ______________________

____

2. RATE THE EASE OF ADJUSTING THE FIT OF THE ICPO.

____ Very easy
____ Easy
____ Somewhat difficult
____ Very difficult

Comments/Problems: ______________________

____

3. WHILE WEARING THE ICPO, DID YOU EXPERIENCE ANY COMPATIBILITY PROBLEMS WITH OTHER ITEMS OF CLOTHING/EQUIPMENT? (circle yes or no and comment if yes)

STANDARD 25 MIL CB GLOVES	YES	NO
CHEM PROTECTIVE FOOTWEAR COVERS	YES	NO
MCU-2/P PROTECTIVE GAS MASK	YES	NO
CRANIAL	YES	NO
VEST	YES	NO

Comments/Problems: ______________________________

____

4. WERE THERE ANY PARTICULAR PARTS OF THIS ICPO (VELCRO, HOOD, SLEEVES, POCKETS, ETC) THAT GAVE YOU PROBLEMS? (circle one and comment if yes)

YES NO

Comments/Problems: ______________________________

____

5. HOW EASY WAS IT TO USE THE CLOSURES ON THIS ICPO?

____ Very easy
____ Easy
____ Somewhat difficult
____ Very difficult

Comments/Problems: ______________________________

____

6. BASED ON YOUR EXPERIENCE WITH THE CURRENT CPO, HOW WOULD YOU RATE THIS PROTOTYPE ICPO COMPARED TO THE CURRENT CPO? (check one in each column)

	OVERALL	COMFORT	FIT	DURABILITY
MUCH BETTER	____	____	____	____
SOMEWHAT BETTER	____	____	____	____
THE SAME	____	____	____	____
SOMEWHAT WORSE	____	____	____	____
MUCH WORSE	____	____	____	____

Comments/Problems: ______________________________

____

7. DID YOU EXPERIENCE SKIN PROBLEMS BECAUSE OF THE ICPO, OTHER THAN PERSPIRATION? (circle one and comment if yes)

YES NO

Comments/Problems: ______________________________

____

8. WAS THE ICPO SUITABLE FOR WEAR IN THE TEMPERATE AND WEATHER CONDITIONS YOU TESTED IN? (circle one and comment if no)

YES NO

Comments/Problems: ______________________________

____

9. HOW WOULD YOU SAY THIS ICPO FITS YOU? (check one)

____ FITS UNUSUALLY WELL
____ FIT IS ABOUT AVERAGE
____ FIT NEEDS IMPROVING
____ FIT IS POOR

Comments/Problems: ____

____

10. HOW WOULD YOU RATE THE ADEQUACY OF THE POCKETS ON THIS ICPO? (check one in each column)

	LOCATION	ACCESSIBILITY	SIZE
VERY GOOD	____	____	____
GOOD	____	____	____
BARELY ADEQUATE	____	____	____
POOR	____	____	____

Comments/Problems: ____

____

11. HOW WOULD YOU RATE THE FREEDOM OF MOVEMENT WHILE WEARING THIS ICPO?

____ VERY GOOD
____ GOOD
____ BARELY ADEQUATE
____ POOR

Comments/Problems: ____

____

12. BRIEFLY DESCRIBE WHAT DUTIES YOU ARE REQUIRED TO PERFORM IN THIS TEST SCENARIO.

____

____

____

13. DID THE ICPO ALLOW YOU TO PERFORM YOUR DUTIES WITHOUT ANY COMPLICATIONS OR PROBLEMS? (circle yes or no and comment if no)

YES NO

Comments/Problems: ____

____

14. DID YOU FIND ANY SAFETY-RELATED PROBLEMS ASSOCIATED WITH THIS ICPO? (circle yes or no and comment if yes)

YES NO

Comments/Problems: ______________________________

____

15. DID YOU EXPERIENCE ANY RIPS, TEARS, HOLES IN YOUR ICPO WHILE WEARING IT? (circle yes or no and comment if yes)

YES NO

Comments/Problems: ______________________________

____

16. WHAT IS THE BEST FEATURE OF THE ICPO AND WHY?

____

____

17. WHAT IS THE WORST FEATURE OF THE ICPO AND WHY?

____

____

18. IF YOU COULD CHANGE ANYTHING IN THIS ICPO TO IMPROVE IT, WHAT WOULD IT BE AND WHY?

____

____

19. ADDITIONAL COMMENTS: ______________________________

____

____

____

____

____

APPENDIX C

MODIFIED CPO AND ICPO QUESTIONNAIRE COMMENTS

Physical Compatibility Questionnaire Comments for Simulated Flight Deck Operations Conducted at NAEC with the Modified NAEC CPOs

Characteristic		Comments	
Donning	1.	Sweat in eyes.	1
	2.	Difficulty getting hood over cranial helmet.	2
	3.	Footwear covers difficult to get on right away.	1
	4.	Trousers difficult to put on over flight deck boots.	3
	5.	More practice required.	1
	6.	Requires assistance to don.	1
Ease of Adjusting Fit	1.	Difficult to adjust mask by yourself.	2
	2.	Could not get a good seal at wrist interface.	1
	3.	Difficult fitting hood over cranial, need another person.	2
	4.	No problems.	1
Compatibility with IPE	1.	Footwear cover coming loose.	1
	2.	Boots too large	1
	3.	Air intake blocked with head turned.	1
	4.	Difficult to see out of sides of mask.	1
	5.	Mask too tight.	1
	6.	Mask made it difficult to turn head.	1
	7.	Downward vision obscured by bottom of glass in mask.	1
	8.	Hood would not fit over cranial.	1
	7.	Downward vision obscured by bottom of glass in mask.	1
	8.	Hood would not fit over cranial.	1
	9.	Gloves too large.	1
	10.	Cranial too tight.	3
	11.	Cannot use cranial/mask/communications combo.	1
	12.	Reduced tactility necessary to operate buttons.	1
	13.	Footwear should be larger for size 13 and above.	1
Component Problems	1.	Footwear coming loose.	1
	2.	Boots too bulky (felt like I was wearing flippers).	2
	3.	Hood too tight reducing the ability to turn your head.	1
	4.	Difficult to get hood over cranial.	1
	5.	Velcro fastener did not take up adequate slack.	2
	6.	Problem securing hood around mask.	1
	7.	Trousers kept sliding up (subject only 6 ft. 1 in.).	1

Physical Compatibility Questionnaire Comments for Simulated Flight Deck Operations Conducted at NAEC with the Modified NAEC CPOs (Continued)

Characteristic		Comments	
Ease of Using Closures	1.	Velcro fasteners did not take up adequate slack.	1
Skin Problems	1.	Excess sweating under gloves.	1
	2.	Mask rubbing on face.	1
Experience Discomfort, Temperature Conditions	1.	Too warm in sun, wind helps.	1
	2.	Hard to breathe.	1
	3.	Depends on weather.	1
Fit of Modified CPO	1.	It felt pretty good.	1
	2.	Too big (both comments from small subjects).	2
	3.	Hood tight over cranial.	1
	4.	Pants difficult to don over flight deck boot.	1
Comfort	1.	Mask was not giving sufficient oxygen.	1
	2.	Movement of head is awkward/difficult/uncomfortable.	3
	3.	Movement of feet is awkward.	1
	4.	Suit gets pretty hot inside (requests air vent).	1
Adequacy of Pockets	1.	For flight deck work there should be no pen pocket, FOD potential.	1
Freedom of Movement	1.	Difficulty with head movement.	5
	2.	Mask allows little movement.	1
	3.	Feet weighted down.	1
	4.	Boots sliding off.	1
	5.	Movement OK but not a lot of freedom.	1
Ability to Perform Duties	1.	Good mobility	1
	2.	Problems backing up due to head movement restriction.	1
	3.	Not enough air in mask.	1
	4.	Gloves catch tractor ring when disconnecting tow bar.	1
	5.	Gloves are bulky making fingers useless.	1
	6.	Could not wear mask and have communications.	1
	7.	Head/boots.	1

Physical Compatibility Questionnaire Comments for Simulated Flight Deck Operations Conducted at NAEC with the Modified NAEC CPOs (Continued)

Characteristic		Comments	
Any Safety Problems	1.	Tripping on boots.	2
	2.	Hard to breathe in mask while running.	1
	3.	Visibility fair.	1
	4.	Movement good (other than head).	1
	5.	Slippage in footwear.	1
	6.	Lack of visual on sides.	1
	7.	Gloves would not work well if wet.	1
	8.	The boots.	2
	9.	Little allowance for head movement with hood on.	1
Any Damage to Modified CPO		NO COMMENTS	
Best Features of the Modified CPO	1.	The velcro.	1
	2.	Good fit.	1
	3.	Thin material making movement good.	1
	4.	Lightweight.	2
	5.	The smock fit well.	2
	6.	The coat.	1
	7.	Taking it off.	1
	8.	Drinking tube.	2
	9.	Breeze.	1
	10.	Pants and top.	2
	11.	Lens did not fog up like most masks.	1
	12.	Large pockets.	1
	13.	The straps.	1
	14.	Covers whole bottom well.	1
	15.	Vest/hood.	1
Worst Features of the Modified CPO	1.	Glove.	1
	2.	Hood.	1
	3.	Hot, it make you sweat.	2
	4.	Mask and hood, cranial.	1
	5.	Hard to work with while looking toward sun.	1

Physical Compatibility Questionnaire Comments for Simulated Flight Deck Operations Conducted at NAEC with the Modified NAEC CPOs (Continued)

Characteristic	Comments	
	6. That it vary with the weather.	1
	7. Mask.	3
	8. Boots.	3
	9. Boots too big.	1
	10. Pants too big.	1
	11. Hood to put over cranium.	1
	12. Boots look terrible.	1
	13. Putting it on, moving and performing duties in it.	1
What Would You do to Improve the Modified CPO	1. Put in AC.	1
	2. Dinner jacket.	1
	3. Gloves.	1
	4. Hood.	1
	5. Better fit.	1
	6. Nothing.	3
	7. Head area for better improvement.	1
	8. Put a tinted lens on the mask.	1
	9. Rainproof and windproof.	1
	10. Easier to don.	1
	11. Better breathing in mask.	1
	12. Allow for eyeglasses.	1
	13. Boots.	4
	14. Instead of putting the rubber boots over the flight deck boots, how about removing the flight deck boots and come up with a one-piece boot that has a steel toe?	1
	15. Boots too bulky, but good as far as weight, make a smaller size boot.	1
Overall Preference for the Modified CPO Versus the CPO	NO COMMENTS	

Interim Chemical Protective Overgarment Operation Demonstration Questionnaire Comments for Ships and Port Based Unit

Characteristic	Comments
Donning	1. Need another person to help don. 2. It takes more time to don than CPO. 3. Difficult to don pants with boots on. 4. Weird to figure out. 5. Difficult to put the hood over the mask and tieing it. 6. Needed help to secure hood around mask. 7. A lot more comfortable than the last ones. 8. Takes two to don the hood properly. 9. Hot and tight to wear, especially the bottom part of the trousers. 10. Tightness around mask could have been slightly better.
Ease of Adjusting Fit	1. It is hard to find the right strap especially once the mask is on. 2. The ICPO is easy to adjust once you have donned it. 3. No problems adjusting, easier than the CPO suit because it was too large. 4. Rubber gloves make donning suit more difficult. 5. Hood is a little bit hard to adjust. 6. Just a need to familiarize self with ICPO.
Compatibility with IPE	1. Glove hard to don, hard to get under sleeve.
Component Problems	1. Hood hard to look or move my head around. 2. The hood seems to work itself loose when you move your head a lot. 3. Too hard to adjust hood. 4. Hood is nearly impossible to secure with gloves. 5. The elastic sleeves were a great idea in protection.

Interim Chemical Protective Overgarment Operation Demonstration Questionnaire Comments for Ships and Port Based Unit (Continued)

Characteristic	Comments
	6. It leaves some charcoal marks on the skin (on the corners of your skin). 7. Hood took to long to don, pocket in the wrong spot. 8. The wrist velcro straps for me were hard to don. They would not reach around to stick. 9. The scrim makes a black mark on my clothes and my body. 10. The scrim hindered the lacing of my boots. 11. Hoods.
Ease of Using Closures	1. All except hood, which you cannot see or feel if it is correct. 2. Hard for you to zip up. 3. The zipper on the jacket made donning the ICPO much easier than the current suit. 4. Hood took too long to tighten. 5. Felt I was not completely air tight.
Skin Problems	1. Charcoal remains on the skin. 2. Leaves black marks on it.
Experience Discomfort, Temperature Conditions	1. Just a little hot. 2. None. 3. I cannot expect to be air conditioned. 4. It is hot when your inside the ship. 5. But if it got hotter (like in the Persian Gulf) it will be very hot. 6. In this San Diego cool environment it was comfortable. In the Persian Gulf, I would be somewhat restricted. 7. It was hot and the ventilation was shut off.
Fit of ICPO	1. The ICPO is just a little baggy. 2. Fit very well. 3. I could not move around freely in this suit.

Interim Chemical Protective Overgarment Operation Demonstration Questionnaire Comments for Ships and Port Based Unit (Continued)

Characteristic	Comments
Adequacy of Pockets	1. Size of pockets could be larger.
Freedom of Movement	1. Hood/hard to look or move my head around. 2. I had a little problem with movement around the neck area.
Ability to Perform Duties	1. Hood/hard to look or move my head around. 2. The mask enable me to put my head in small places.
Any Safety Problems	NO COMMENTS
Any Damage to ICPO	1. In the seat of the pants from sliding under equipment.
Best Feature of the ICPO	1. Velcro fasteners. 2. It will give more protection due to the fact of the more fastener straps and velcro. 3. The gas mask. It allows good vision. 4. The best feature were the gloves because they were not in my way. 5. The easy way to put on the suit and much more durable. 6. It fits better than the old one. 7. Front zipper and pockets. Easily put on and storage. 8. Closure were you zip it up. 9. Zipper-makes it easier to don and doff the suit. 10. Easier to wear, gives extra protection in covering the gloves. 11. It allows you to move freely, and it is cooler than the CPO. 12. The pants you can put them on a little faster. 13. Compatible and easy to don. 14. How easy it is to don. 15. The whole thing, it is comfortable on your body. 16. Easy to wear and it does not stink. 17. Protection. 18. Ease of wearing and working with suit on. 19. Thicker than the CPO, better protection.

Interim Chemical Protective Overgarment Operation Demonstration Questionnaire
Comments for Ships Port Based Unit (Continued)

Characteristic	Comments
Worst Feature of the ICPO	1. The boots, they are a little clumsy to move in. 2. My pants were too tight. 3. Trying to tighten up the hood. 4. Hood-hard to properly adjust. 5. Hot. 6. Wearing the mask. 7. Hood adjustment takes a long time. 8. It leaves charcoal marks on the corner of your skin. 9. The zipper, it may get stuck and that will cause you time you may not have. 10. Cannot say there is one. 11. I did not experience any bad features while using it. 12. Nothing. 13. Size. 14. Just the lack of knowledge as to being completely air tight. The question about heat in a hot environment. 15. The charcoal on my uniform. 16. Too thick, bulk, and heat.
What Would You do to Improve the ICPO	1. Nothing, 4 responses 2. I would install zippers in the pant legs for quicker and easier donning with working boots. 3. I would just hook the gloves on it so you can just slip it on easily. 4. Remove zipper on hood and use flash hood. Speed of donning. 5. Put pockets on the left sleeve for pens and note pads. 6. Hood. 7. Make them waterproof. 8. The inner charcoal cloth wouldn't come off on your clothing. 9. The scrim, it must be changed to prevent leaving marks.

Interim Chemical Protective Overgarment Operation Demonstration Questionnaire Comments for Simulated Flight Deck Operations Conducted at NAEC

Characteristic	Comments
	10. The velcro (not the straps) need to be larger so we can tighten it up to fit. 11. Size. 12. *Try to make it cooler.* 13. I would make the material a little thinner. 14. Built in ice packs.
Overall Preference for the ICPO Versus the CPO	1. Appears to be much more durable. 2. Not enough time to comment on durability. 3. I never wore the CPO.
Donning	1. Takes too long, need a one piece suit. 2. After donning the mask I had trouble completing the hood portion; zipper, velcro, etc. 3. Takes a long time to don the suit.
Ease of Adjusting Fit	1. Hood Adjusting. 2. The suit was more comfortable than I expected, and was not complicated.
Compatibility with IPE	1. The suit fit pretty good. 2. It wasn't easy to hear another person talking through the gas mask.
Component Problems	1. Hood.
Ease of Using Closures	NO COMMENTS
Skin Problems	NO COMMENTS
Fit of ICPO	NO COMMENTS

Interim Chemical Protective Overgarment Operation Demonstration Questionnaire Comments for Simulated Flight Deck Operations Conducted at NAEC

Characteristic	Comments
Comfort	NO COMMENTS
Adequacy of Pockets	NO COMMENTS
Freedom of Movement	NO COMMENTS
Ability to Perform Duties	1. Problem when working on an engine on a plane. 2. In extreme heat tiring will occur.
Any Safety Problems	NO COMMENTS
Best Features of the ICPO	1. Movement. 2. Pants. 3. Everything is matched well. It fit well.
Worst Features of the ICPO	1. Hood. 2. Being enclosed and heat involved.
What Would You do to Improve the ICPO	1. Hood, 2 responses. 2. It is fine, well built.
Overall Preference for the ICPO Versus the CPO	NO COMMENTS

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